THE
SOIL AND CROP SCIENCE
SOCIETY OF FLORIDA

PROCEEDINGS
VOLUME 19
1959

Nineteenth Annual Meeting of the Society
University of Florida
Gainesville
November 30, December 1 and 2, 1959

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1960

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CONTENTS

Acknowledgments 5
New Honorary Lifetime Member 6
Honorary and Sustaining Members 7
Dedication 10
Development and Present Status of Extension Programs in Soils and Field Crops ..... M. O. Watkins 11
Honor Guest 16
Development and Present Status of Teaching Programs in Field Crops and Soils ..... G. D. Thornton and E. G. Rodgers 18

TWENTY YEARS OF PROGRESS IN SOILS RESEARCH IN FLORIDA
W. L. Pritchett, Presiding

Progress in Soils Research, 1939-1959 ..... F. B. Smith 23
Soil Morphology and Classification ..... R. E. Caldwell and R. G. Leighty 30
Soil Microbiology in Florida, 1939-1959 ..... G. D. Thornton and C. F. Eno 39
Manganese in Florida Soils—a Review ..... D. F. Rothwell 51
Soil Acidity and Liming ..... G. M. Volk 66
Effect of Twenty Years of Fertilization of Florida Soils ..... John G. A. Fiskell 72

TWENTY YEARS OF PROGRESS IN CROP BREEDING IN FLORIDA
F. H. Hull, Presiding

Small Grain Breeding in Florida During The Past Twenty Years ..... W. H. Chapman 91
A History of Field Corn Breeding in North Florida ..... E. S. Horner 99
Soybean Breeding in Florida ..... Kuell Hinson 105
Peanut Breeding in Florida ..... W. A. Carver 115
Lupines For Forage Production ..... J. R. Edwardson and M. K. Corbett 119
Tobacco Breeding in Florida During The Past Twenty Years ..... C. E. Dean 132

TWENTY YEARS OF PROGRESS IN PASTURE DEVELOPMENT IN FLORIDA
N. Gammon, Jr., G. B. Killinger, and E. M. Hodges, Presiding

Economic Factors Influencing Pasture Development in Florida During the Past Twenty Years ..... W. K. McPherson 139
Beef Cattle Improvement in Florida Over The Past Twenty Years —W. G. Kirk and F. M. Peacock 147
Pasture Development at the Range Cattle Station ..... E. M. Hodges and J. E. McCaleb 150
Pasture Development in the Everglades ..... R. J. Allen and F. T. Boyd 154
Pasture Herbage Changes in Florida During the Past Two Decades (1939-1959) ..... Gordon B. Killinger 162
Changes in Pasture Fertilization —Nathon Gammon, Jr., R. J. Bullock and J. R. Neller 166
The Evaluation of Cold Hardiness in Florida Pasture Grasses —Leonard S. Dunavin, Jr. and O. C. Ruelke 172
Effect of Rate and Frequency of Nitrogen Application on Yield and Quality of Pangolagrass ..... R. W. Prevatt and J. C. Engibous 179

CONTENTS (Cont'd)

TWENTY YEARS OF PROGRESS IN RESEARCH ON PRODUCTION OF GENERAL FIELD CROPS IN FLORIDA

Fred Clark, W. K. Robertson, and V. E. Green, Jr., Presiding

A Review of Plant and Water Relations ..... G. M. Prine and S. H. West 184
Fertilizer Placement Studies on Farm Crops ..... W. K. Robertson and C. E. Hutton 190
Plant Populations and Nitrogen Fertilization For Field Corn in North Florida
—E. S. Horner, D. E. McCloud, and I. M. Wofford 197
Research on Peanuts During the Last Twenty Years ..... Harry C. Harris 208
Soybean Production in Western Florida ..... R. L. Smith 226
Early Work With Field Crops in Northern and Western Florida
—R. W. Lipscomb and R. W. Wallace 231
Twelve Years of Progress on General Field Crops in Northern Florida
—L. G. Thompson, Jr., R. W. Lipscomb and W. K. Robertson 240
Recent Progress in General Crop Production in Western Florida
—C. E. Hutton and M. C. Lutrick 256
Progress in Research on Field Crops in Southern Florida 1939-1959
—Victor E. Green, Jr. 252
Progress in Research on Shade Tobacco Disease Control, 1922-1959 Randall R. Kincaid 252
Progress of the Flue-Cured Tobacco (Type 14) Industry in Florida. 1939-1959
—Fred Clark and S. L. Brothers 276
A Brief Review of Sugarcane Research in Florida 1939-1959
—T. Bregger, P. H. Dunckelman, F. le Grand, E. H. Todd, and D. D. Questel 287
Summary of Advances in Fiber Crops Production in South Florida During the Past Twenty Years ..... R. V. Allison 295

CONTRIBUTED PAPERS—*A. T. Wallace, Presiding*

Early Experiences with Hydroponics at The Public Health Research Laboratories ..... Denes K. Markus 339
Water Table Fluctuations on Organic Soils During Periods of Drainage and Irrigation ..... D. S. Harrison 352
Water Damage to Citrus in the Indian River Area in 1959 ..... R. R. Hunziker 357
Comparison of Photosynthetic and Respiratory Rates in Some Florida Pasture Grasses ..... Vincent N. Schroder and O. Charles Ruelke 365
Pasture Grasses found Suffering from Phosphate Deficiency on Virgin Everglades Peat Soil ..... H. J. Andreis 369
Iron Chlorosis in Roselawn St. Augustine Grass Growing on Muck Soils of the Everglades ..... Ferdinand le Grand 374
Recovery of Nitrogen from Several Sources by Oats and Millet
—G. M. Volk, W. H. Kelly and W. G. Blue 379
Studies of the Seed-borne Phase of Brown Spot (Pleiochaeta Setosa (Kirchn.) Hughes) in White Lupine (Lupinus Albus L.) ..... Stanley A. Ostazeski 385
Blackheart of Chicory ..... P. J. Westgate and R. B. Forbes 389
John Clayton Gifford (1870-1949), and the Florida Everglades ..... Geoffrey J. Martin 394
Interaction of Water and Gamma Irradiation on Seedling Vigor ..... Alvin T. Wallace 397
Effects of Liming on Yield and Value of Flue-Cured Tobacco in the Suwannee Valley Area ..... H. L. Breland, W. L. Pritchett, and H. L. Lundy 409
Effects of Nitrogen Fertilizer on the Yield and Composition of Flue-Cured Tobacco ..... W. L. Pritchett, H. L. Breland and H. W. Lundy 418

CONTENTS (Cont'd)

TWENTY YEARS OF PROGRESS IN CONTROLLING PESTS OF FLORIDA FIELD CROPS

Weed Control In Pastures With Sandy Soils in Peninsula Florida —J. E. McCaleb and E. M. Hodges 305
Chemical Weed Control in Agronomic Crops on Florida's Organic Soils —J. R. Orsenigo 308
Weed and Brush Control in North Florida ..... E. G. Rodgers 318
Progress in Control of Insect Pests of Florida Field Crops During The Last Twenty Years ..... A. N. Tissot 325
A Review of the Research on the Diseases of Agronomic Crops and their Control in Florida 1939-1959 ..... Phares Decker 330

SYMPOSIUM: NEMATOLOGY IN THE TROPICAL AND SUB-TROPICAL ZONES OF THE WESTERN HEMISPHERE

A. C. Tarjan, Presiding

Introduction ..... A. C. Tarjan 428
Phytonematology in Panama and Central America ..... Rogelio Cuellar S. 430
Nematode Problems of the Banana Plant ..... E. J. Wehunt and Q. L. Holdeman 436
Observations on Some Subtropical Plant Parasitic Nematodes in Florida —L. G. van Weerdt, W. Birchfield and R. P. Esser 443
The Possibilities of Biological Control of Plant-Parasitic Nematodes in Tropical and Sub-Tropical Areas ..... William A. Feder 452
Banquet and Business Meeting 464
Meeting of the Executive Committee 468
Resolution of Sympathy 471
Officers of the Society 472
Constitution and By-laws 473
Authors Guide for preparing Papers for the Soil and Crop Science Society of Florida Proceedings 475
Annual Members 478

ACKNOWLEDGMENTS

The Executive Committee of the Soil and Crop Science Society of Florida wishes to thank the Officials of the College of Agriculture of the University of Florida for making available the splendid facilities in Dan McCarty Hall for the 1959 Annual Meetings.

The entire membership acknowledges with grateful thanks the beautiful gavel presented to the Society by Mr. R. L. Bryan, President of Lake Garfield Nurseries Company, Bartow, Florida. It was presented to President P. H. Senn just in time for calling to order the initial session of the Nineteenth Annual Meeting at 1:30 P.M. on Monday, November 30, 1959.

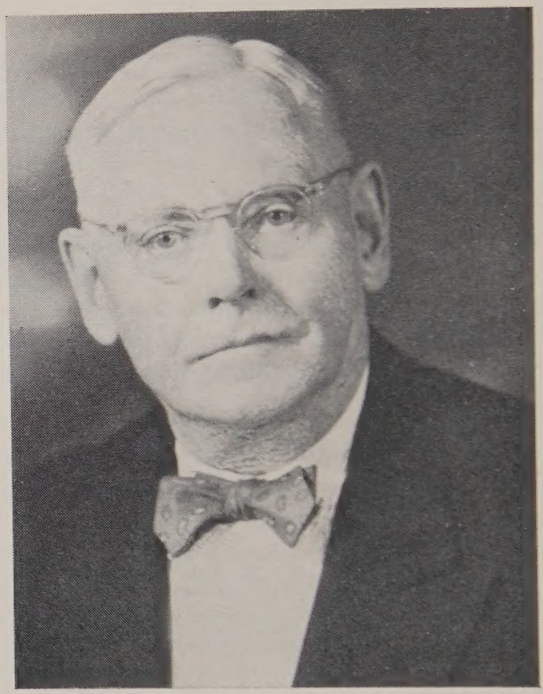
The membership of the Society is greatly indebted to Dr. Marshall O. Watkins, Director of the Agricultural Extension Service of Florida for the splendid address which he delivered at the annual banquet on the evening of December 1. Since the theme of the Nineteenth Annual Meeting of the Society was "Twenty Years of Progress in Research, Teaching and Extension in Soils and Field Crops in Florida," Dr. Watkins' subject, "Development and Present Status of Extension Programs in Soils and Field Crops in Florida" was most timely.

The Committee extends its thanks to Dr. George D. Scarseth, Director of Research, American Farm Research Association, Lafayette, Indiana, for appearing on our banquet program and bringing "Greetings to the Society from the Cornbelt." His timely and humorous remarks were warmly received.

Words of appreciation are extended to Drs. D. O. Spinks and A. J. Norden, who as a committee, handled so efficiently all arrangements for the annual banquet. Also, to Drs. R. E. Caldwell and O. C. Ruelke for capably handling arrangements and providing projection services in connection with the many papers and reports presented at the various sectional meetings.

The Executive Committee also expresses its thanks and appreciation to all who actively participated in the program of the Nineteenth Annual Meeting of the Soil and Crop Science Society of Florida. Special thanks go to those, of course, who responded so promptly in making their manuscripts available so press work could go forward without delay on the now current Proceedings, Volume 19, 1959.

NEW HONORARY LIFETIME MEMBER



WILSON POPENOE (born in Topeka, Kansas, 9 March 1892) began work in subtropical and tropical horticulture fifty years ago, when at the West India Gardens in Altadena, California, he grafted the first trees of the Fuerte avocado, introduced from Mexico. In 1912 he and his brother Paul went to India, Arabia, and North Africa, whence they brought back new mango varieties and 16,000 young palms which provided a great stimulus to the young date industry in California and Arizona.

On his return from this around-the-world voyage, Wilson joined the staff of the Office of Foreign Seed and Plant Introduction, in the U. S. Department of Agriculture at Washington, where under the inspiring direction of David Fairchild he spent twelve years as an Agricultural Explorer, traveling from Mexico to Chile in search of new crop and ornamental plants for introduction into the United States. Avocados were a major objective.

In 1925 he left the Department to enter the service of the United Fruit Company. His first job was to establish an experiment station at Tela, Honduras, where were brought together economic plants from all over the tropical world. This station, still active, has done much work on rubber, abaca or Manila hemp, bamboos, timber trees, bananas and numerous other tropical fruits; and it developed the culture of the African oil palm which is rapidly attaining commercial importance in several tropical American countries.

During the period 1925 to 1940 Popenoe directed tropical research activities of the United Fruit Company which were concerned with soils, drainage, irrigation and cultural practices including the use of inorganic fertilizers on an extensive scale. In 1941 he was detached from these investigations to organize and develop an agricultural school near Tegucigalpa, Honduras, financed by the United Fruit Company, of which he was Director until his retirement in 1957. During his time this school trained more than 600 young Latin Americans from 13 countries, all of whom enjoyed full scholarships. These men have gone out to staff agricultural extension services; some are teaching in agricultural schools; several hold positions as high as Director of Agriculture; and many others are applying the principles of modern agriculture which they learned at Escuela Agricola Panamericana (as the school is called) on their own farms or those of others on which they are employed in responsible positions.

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Wilson-Toomer Fertilizer Co., Box 4459, Jacksonville
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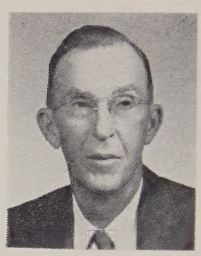
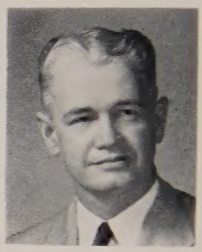
Wishnetsky, Dr. Theodore, Eastman Chemical Products, Kingsport, Tenn.
Woods, F. J. and L.P., Box 2721, Tampa
Zipperer, J. O., Box 632, Fort Myers

Dedication

To the Work and the Workers in the
Florida Agricultural Extension Service. 1939-1959.



H. G. Clayton
Director
1947-1956



M. O. Watkins
Director
1956-

A. P. Spencer
Director
1939-1947

County Agricultural Agents, District Agents and others, including Specialists, who have been continuously active in the work of the Florida Agricultural Extension Service thru the period 1939-1959.

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Clifford R. Boyles
Harry J. Brinkley
S. L. Brothers
J. Francis Cooper
W. P. Hayman
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Thomas R. Townsend
James H. Walker
Marshall O. Watkins*
Alec White*
Robert Yates

*Indicates charter membership in the Society.

Development and Present Status of Extension Programs in Soils and Field Crops

M. O. Watkins[1]

In preparing my remarks for this talk, I was struck by two things. First, the time span of 20 years included in the theme for the meeting this year. At a glance this appears to be a long time, and it is. But measured in terms of progress, and in terms of the programs required to bring about that progress, it is not long. Progress that is fundamental and basic does not happen overnight, in either teaching, research or extension.

Second, I was struck by the fact that in all areas of field crops and soils, we are making real progress, step by step, in our efforts to keep Florida agriculture efficient and competitive with other producing areas throughout the country.

In the beginning, I would also like to pay tribute to Extension's co-workers in research throughout Florida—for their cooperation and helpfulness. Without their days and weeks of painstaking research our Extension programs would be without substance. Also, to those in teaching, our thanks for your help with our training programs, and for turning out the kind of Agricultural graduates we are proud to name as county agents and specialists.

In my opinion, without the close working relationships of these three divisions, our progress would have been much slower.

In my remarks tonight, I am hitting some high points and covering more of the "how" things were done and who did them than "what" was done. "What" was done is well-known by you in research who developed the information. "How" it was incorporated into the minds of farmers, their programs and annual plans is more the responsibility of Extension.

I might point out that a great deal of the progress that Extension has made in field crops and soils has been in getting ready, personnel wise, to do the job.

It has been our experience, acquired over many years of Extension work, that specialists are essential to getting research results adopted by growers. In the earlier days of Extension the thought seemed to be that specialist assistance to county agents was necessary only when the agent encountered some sort of emergency, and then a member of the teaching or research staff could run out and help him diagnose the problem, assist him with a meeting or otherwise take care of the hurting situation of the moment.

We now know that county agents need a lot more help than that if they are to make effective use of research. The specialist must keep current on all research in his field, U.S.D.A. and state, branch station and field laboratory. He must organize this material in such a way that the agents can use it effectively, using bulletins, news releases, radio, etc. He must train county agents in its use, and work with them to include it in their county programs with farmers. In so doing, he ties in the research material with problems which farmers recognize, such as low yields, disease, etc., and which then become a part of the county Extension program. The difficulty involved in getting a new practice or package of practices adopted will depend, of course, on the type of farmers being worked with, whether or not

[1]Director, Agricultural Extension Service, University of Florida, Gainesville. Address following Annual Banquet Monday evening, Dec. 1, 1959.

they recognize a problem, and how difficult it is to convince them that they will make more money if they adopt the practice(s).

In 1939, Extension had only one part-time specialist in agronomy whose major duties were supervisory. However, I would hasten to add that the late J. Lee Smith was a most effective person who preached the gospel of field crops varieties, fertilization, etc., as vigorously as possible as he made his district agent rounds in North and West Florida. This was the situation until a little over a decade ago when in 1947 the present agronomist, Russell Henderson, was employed on a part-time basis. Extension now has three full-time agronomy specialists, a soils specialist, and a number of others who devote part of their time to field crops, pastures and soils work, including an entomologist, a pathologist, economists, engineers and others. Also, for a number of years, Extension has had an Extension conservationist, first in cooperation with the Soil Conservation Service and now on a full-time Extension basis. As a sidelight, I think you would be interested in the fact that at the end of World War II, Extension had a total of two part-time and six full-time subject matter specialists. We now have six part-time and 35 full-time specialists.

Now with this bit of background and as briefly as possible, what has been done, how, and by whom? I shall touch on only a few of the high points in some of the major crops.

Flue-Cured Tobacco. Back in 1939 flue-cured tobacco production in Florida was still in its infancy. Growers generally were ignorant of the fine points of production, as evidenced by the fact that they paid demonstrators to show them how to produce it. County agents, too, lacked experience in this field. The average yield per acre that year was 700 pounds. Incidentally, in 1939 growers voted out acreage allotments and the largest acreage in the history of the state was planted. Allotments were voted back in the next year and have remained in effect since.

The Extension Service now has a full-time tobacco specialist, S. L. Brothers, who has been employed since 1956. I would point out here that Fred Clark of the Experiment Stations has worked closely with tobacco growers over the years. Much of the Extension work in this field has been done by Fred. He now works closely with Brothers.

Today growers are generally rather expert in the production and curing of the crop. County agents in the major tobacco counties are familiar with production practices. Yields per acre have gone from 700 pounds in 1939 to 1503 pounds in 1958.

Hybrid Corn. Hybrids were just coming into existence in 1939. In that year the average corn yield per acre in Florida was 8.2 bushels. The real boost followed the introduction of Dixie 18 about 1948 when the average per acre yield was 10 bushels. I mentioned corn partly because of its economic importance to Florida, past and future, and partly due to the difficulty of introducing hybrids. Farmers were extremely reluctant to give up the tried and true method of selecting their seed corn from the best ears in the crib. Countless demonstrations were necessary, using 4-H projects and every method in the Extension book to get farmers to use hybrids. The job has finally been accomplished and yields have risen from the 8.2 bushels per acre in 1939 to 26 bushels in 1958, due in large part to hybrids and better fertilization. Work with corn will continue to be an important part of Extension work. Last year some 1500 4-H Club members completed demonstration projects in corn. Their work was climaxed with the State 4-H corn show and Youth Day at North Florida Fair.

Other field crops. While I am supposed to cover only Extension work, I would point out that outstanding research work has been done with oats, rye, peanuts, and other field crops, primarily in the area of breeding. Growers have been kept informed on this work. Yields on these crops have improved spectacularly. Extension work on cotton has declined in the past two decades due to the declining importance of the crop and the fact that Florida is not able to compete successfully with western and delta states.

With these and the other crops Extension has learned that those who sell to farmers must be kept informed and on the team if maximum progress is to be made. At one time county agents handled orders for seed themselves in order to have them available to farmers. Today the agronomists hold regular meetings with seedsmen and fertilizer dealers to keep them informed on new varieties, fertilizer, disease and insect control. The Florida Seedsmen's Association helps Extension disseminate this information to the farmers when they buy their supplies and its members try to stock the recommended seeds and materials. I might also add that a series of production guides prepared by Extension agronomists has been most helpful in placing concise agronomic information in the hands of users.

In connection with new varieties the old original Crop Improvement Association helped keep growers supplied with seed.

In 1958 it was replaced by the Foundation Seed Producers Association, which serves to multiply varieties released by the Stations and to make them available to the general public in the quickest possible time. For several years prior to the establishment of this association the Extension agronomist solicited applications and alloted station produced foundation seed of new varieties to qualified growers.

Permanent pastures have made steady progress since about the beginning of this twenty-year period. Aided by government payments through the A.C.P., (incidentally the A.C.P. was largely operated by county agents in the 30's), spurred on by the passage of the no-fence law and encouraged by the original eradication of the fever tick, cattlemen have been putting in more pastures each year until at present there are some 2.3 million acres in the state. Extension is proud of the fact that one of its then county agents, Ed Finlayson, discovered the most popular variety of permanent pasture grass in use today—Pensacola Bahia, thus giving a quick boost to research efforts in this field. At present Extension has an agronomist working as an associate county agent in a five county area in the Everglades. Part of his intensive work with cattlemen has been to speed up the planting of permanent pastures where needed and practical.

Winter legumes in pastures have had their ups and downs. It has been difficult to sell cattlemen on the practicality of putting that much money into an acre of rangeland. The old open range, limited management theory, in the cattle industry is still there. Dairymen have been a little easier to sell and have made more progress. The Extension dairyman, the Extension agronomist and the old Florida Dairy Association carried out an intensive pasture development program for a number of years. This program also helped sell cattlemen. White, crimson, and other clovers are holding their own and then some.

The Extension agronomists and county agents have worked closely with state and county cattlemen's associations in efforts to speed up progress. The annual Cattlemen's Institute at Camp Cloverleaf has helped considerably to put the program across, and I might mention that the severe

freeze of 1957-58 also had its effect in this area as well as to encourage winter feeding.

Soils. I previously mentioned that we had an Extension conservationist. This man carries on a program of education in soil and water conservation, working closely with the Soil Conservation Service, the State Soil Conservation Board and Agricultural Stabilization and Conservation. A highlight of his program at present is the land judging schools and contests he carries out with youth through the county agents.

Soil testing has been a somewhat controversial subject among soil and crop scientists for many years. I shall not dwell much on history. Efforts to develop field crops fertilization recommendations based on soil tests began in 1953. Correlating soil test results with crop response was begun by the Extension agronomist in that year, working with county agents and in cooperation with research workers of the Soils Department here at the University.

For many years county agents have tested soils for pH using colorimetric methods and in a few instances, glass electrode equipment. Two counties, Dade and Escambia, have soils laboratories for complete testing work. Some of the Branch Experiment Stations and the Main Station at Gainesville have been accepting soil samples from the general public and running tests which vary from pH to complete analysis. There are several commercial laboratories and numerous fertilizer companies who do soil testing work. For some time the number of samples received at Gainesville has been on the increase. For example, in 1950 the laboratory processed 2,142 samples and performed 9,622 separate determinations on these samples. In the year 1958-59, 17,128 samples were processed with 137,021 individual determinations made. The load had accordingly increased to the point that it interfered seriously with soils research. In 1958 the Director of the Experiment Stations suggested that the Extension Service assume responsibility for the test work with the public at the beginning of the 1959-61 biennium.

After conferences with county agents, specialists, fertilizer industry people, commercial laboratories, the Board of Control and the Legislature, policies were worked out, and the Legislature approved the transfer. The soils specialist, then Dr. Granville Horn, and now Dr. James NeSmith, added to the Extension staff by the 1957 Legislature, was placed in charge of this work.

The program as it was worked out and now operates makes soil testing work at the University of Florida a diagnostic tool for county agents. All samples are submitted by agents and no samples are accepted unless they come from an agent. All results go back to agents for recommendations. Previous to the transfer, recommendations to growers had been made by county agents, specialists and research people.

A major job in connection with the transfer was to assemble all available information on nutrient levels from State and USDA research workers and Extension workers in order to establish high, medium and low categories. Through the good efforts of all working together, this was done and county agents are able to make modifications in fertilizer recommendations based on the levels of the various elements as determined by tests. Conferences were held with county agents to train them in its use. Recommendations are divided into four different categories: (1) Citrus, (2) Vegetables, (3) Ornamentals, and (4) Field Crops, including pastures. In the area of field crops, more advanced information is available due to the

correlation work I have described and more detailed assistance is therefore available to agents. Also, in the field crops area of North and West Florida, a much more comprehensive job of soil testing is being done because: (1) of the more advanced knowledge mentioned, (2) growers are using far less than optimum fertilizer applications, and (3) there are no commercial labs in the area.

Dr. NeSmith and his staff are members of the Soils Department at the University of Florida. They work closely with the research people and research is being carried on to ensure that the methods and procedures used in the laboratory are best for the existing conditions. Agents and specialists are following closely the work being carried on by Dr. C. M. Geraldson at Bradenton and a number are cooperating with him in his work. This could materially affect methods and use of soil testing in the future. I am sure that each person here will want to follow that progress with care.

I think I could summarize Extension's position on soil testing at the present time by saying that it is another tool for determining problem areas and for getting farmers to use recommended applications of fertilizer. It is still far from perfected and must be used with caution and complete understanding of its limitations.

In closing, I would again like to pay tribute to the teaching and research people throughout the State who have been so cooperative with those of us in Extension. With the team approach we have, with the well-trained, dedicated, qualified staff we have in agriculture, Florida cannot fail to continue its advances in soils and field crops.

BIOGRAPHICAL SKETCH OF GEORGE D. SCARSETH

George Dewey Scarseth, Soil Scientist and Agronomist, is Director of Research for the American Farm Research Association. Formerly he was Professor of Agronomy and Head of the Agronomy Department at Purdue University. He has served as Soil Scientist on the teaching and research staffs of the Alabama, Connecticut and Wisconsin Agricultural Experiment Stations. Dr. Scarseth started his scientific career in 1926 as Soil Chemist in Central America for the United Fruit Company. For nearly twenty years he was Agricultural Research Consultant on tropical soil problems for Standard Fruit and Steamship Company, and in recent years he has served as Agronomic Consultant to the University of Alaska. Since 1957 he has been Consulting Agronomist for Central Farmers Fertilizer Company.

He was born on a farm in Trempealeau County, Wisconsin. He served as an undergraduate assistant for four years to Professor Emil Truog at the University of Wisconsin, where he graduated in 1924. He did graduate work at Yale in Geology and Chemistry. As a Du Pont Fellow, he obtained his Ph.D. degree in soil science and plant physiology at Ohio State in 1932 under Professor Richard Bradfield. Dr. Scarseth is a Fellow in the American Society of Agronomy and American Association for the Advancement of Science, and a member of several honorary and scientific societies. He received "Freedoms Foundation Awards" in 1951 and 1952. In 1952, Purdue University conferred on him the honorary degree of Doctor of Science. He was a Delegate to Fifth International Congress of Soil Science, Belgian Congo, 1954.

Banquet Remarks by—George D. Scarseth

Honor Guest from the Corn Belt

You are to be congratulated for having developed this Society. It has become a focal point for the Life Scientists from all the numerous experimental stations of this large and highly diversified state. This society brings you together on the common ground of working as a team of the Greater University, yet you have the privilege of being individualistic scientists.

The Proceedings of your Society are becoming internationally important. I have the pleasure of owning a full set. You can publish your papers freely in this proceedings and this is of great value.

I should let you know that I am almost a citizen of Florida. About 25 years ago, while on the staff at Auburn, I started to acquire some cut-over land in western Florida. Now, this land is a good pulp-wood farm. From what you are discovering, I am certain I could grow a lot of different kinds of crops there if needed.

Your scientists are probably doing more pioneering than you realize. I say this because, to me, the agricultural potential of Florida has hardly been discovered.

In my extensive travels over the climatic belts of the world, I have come to think of sunshine as a commodity. A farmer is really in the business of capturing sunshine. The soil, plant, water, nutrients, pests, diseases, labor, management, etc., are all involved, but when I think of the solar energy reaching the land where the temperatures and rainfall are as favorable for biotic activity as in Florida, I see "new horizons emerging."

Therefore, I throw out a challenge to a group such as this. Be daring in your thinking. Don't beat yourself out in old worn out ruts. Don't think of improving farming in terms of current practices. Current practices were safe for farmers of a past age, but not adequate any more. The old practices belong to an ancient art. The future practices will rest on new basic principles. Try to use more basic fundamentals, with which we are today so richly endowed, and synthesize new approaches.

It leaves me cold to read and hear all about these "sputniks" being shot into the sky from Florida and other places, when I know that within your resources as agricultural scientists you have a much bigger contribution to make for mankind.

I am not your speaker this evening. I delight in the privilege of being with you, and now that I have seen you in action, I want to come again.

Development and Present Status of Teaching Programs In Field Crops and Soils

G. D. THORNTON AND E. G. RODGERS[1]

At the final organizational meeting, when the Soil Science Society of Florida officially came into existence in Hollywood, Florida, on April 18, 1939, a Teaching Committee was established. Dr. F. B. Smith, Professor of Soil Microbiology, was appointed Chairman of this committee to which was ascribed the function, "not only to encourage the teaching of soils but to improve the character of the training that is given on all levels of instruction." It should be pointed out, at the time of its inception, the Society was predominantly a society for Soil Scientists and those interested in promoting further development of research and teaching in this area. However, in 1955, the name of the Society was changed to The Soil and Crop Science Society of Florida which more clearly described the interests of the total membership. It is from the latter viewpoint that training programs in both Soils and Field Crops (Agronomy) will be reviewed.

Prior to 1939, all instruction in soils and field crops was given in the Agronomy Department of the College of Agriculture. The Department offered two curricula, 1) major in Soils, and 2) major in Crops. Subsequent to the publication of the 1939 University of Florida Catalog, both Agronomy and Soils Departments were recognized in the College. The Agronomy Department continued to offer courses in crops and genetics with a curriculum in Agronomy, while the newly named Soils Department offered a curriculum in Soils. Oddly, this change coincided with the establishment of our Society and the span of progress being recognized during these meetings involves growth of two departments, namely Soils and Agronomy.

Progress in instruction for each department will be discussed in the following order:

1. Curricula changes, new course offerings and degree programs.
2. Staff increases.
3. Expanded physical facilities.

FIELD CROPS

(Agronomy)

Two decades ago, undergraduate courses were offered in the areas of field and forage crops, and genetics and plant breeding. Today, five additional courses are offered in the subject matter fields of pastures, weed control, and experimental methods, together with agricultural extension courses which are under the supervision of Agronomy.

Seventeen graduate courses have been initiated during the last 20 years and are offered at this time. Areas of subject matter include crop ecology, experimental statistics, and agricultural extension, as well as various phases of crop production, genetics and plant breeding.

The current generalized curriculum in Agronomy is shown in Table 1. This work represents the courses taken by a student during four years

[1]Prof. of Soils and Assistant Dean, College of Agriculture and Prof. of Agronomy, respectively. The senior author is indebted to Dr. F. B. Smith for the presentation of a portion of this paper before the Society at the 1959 Annual meeting in Gainesville.

of undergraduate study and terminates with receipt of the degree of Bachelor of Science in Agriculture. A majority of the basic sciences, as well as English and Humanities, is taken by the student during his first two years while he is enrolled in the University College. On the other hand, most of his courses in Agronomy and other agriculture, as well as electives, are taken during his junior and senior years when enrollment is in the College of Agriculture. A minor amount of flexibility exists so that the undergraduate curriculum can be designed most appropriately according to the background, abilities, and future objectives of the individual student. Since 1950, 93 students majoring in Agronomy have been awarded the BSA degree.

TABLE 1.—GENERALIZED UNDERGRADUATE CURRICULUM IN AGRONOMY AT THE UNIVERSITY OF FLORIDA IN 1960.

	Semester Hrs.
Chemistry, Physics, Mathematics	14-20
Other basic sciences	15
English and Humanities	16
Agronomy	20
Other Agriculture	27
Electives	34-40
Total	132

Curricula for graduate students are prepared individually and based upon the background of the student and the degree being sought. The Master of Agriculture degree requires a program of at least 36 semester hours beyond the BSA, at least 18 of which must be in graduate courses. Work for this degree may be taken without any major, but for a major in Agronomy or any other department, 12 of the required 18 graduate semester hours must be taken in the major department. No thesis is required in either event, however. Fourteen students have received the MAG degree through Agronomy.

Graduate work leading to the degrees of Master of Science in Agriculture and the Doctor of Philosophy may be taken in Agronomy with a thesis based on individual research in field, forage, or pasture crops, crop ecology, genetics and plant breeding, or weed control. The MSA was offered 20 years ago, but Agronomy was authorized in 1955 to give the Ph.D. Since 1940, 26 students have received the MSA degree and two the Ph.D. degree in Agronomy.

The Agronomy teaching staff has increased markedly since 1940 when it was limited to one professor. Soon after the close of World War II, the influx of veteran students necessitated additional instructors. By 1950, the teaching staff included a total of five professors and instructors. In 1959, the staff includes nine professors actively teaching Agronomy courses, plus six members of the Graduate Faculty who are available for consultation with and supervision of individual graduate students.

Along with the expanded curricula and increased staff have come the necessary additional physical facilities as summarized in Table 2. Six offices are used by the teaching staff and two by graduate students today. One classroom and one small laboratory were available 20 years ago and today these numbers are six and four, respectively, each of which is adequately equipped. In addition, a field laboratory together with adequate

field equipment and ample acreage for demonstrations and research became available in 1950. These field facilities have enabled various crop production procedures and techniques to be taught from a practical viewpoint. This type of training is desired particularly for students having no farm experience.

TABLE 2.—A GENERAL COMPARISON OF PHYSICAL FACILITIES USED IN THE AGRONOMIC TEACHING PROGRAM IN 1940 AND IN 1960.

	1940	1960
Offices, Staff	1	6
Offices, Graduate students	0	2
Classrooms	1	6
Laboratories	1	4
Field Laboratory	0	1
Demonstration and teaching plot land	0	Ample acreage

SOILS

As already pointed out, prior to 1940 the Agronomy Department, College of Agriculture offered a curriculum with an optional major in Soils or Crops. The student electing the Soils option was required to take six additional hours of chemistry as well as five additional hours in the field of Soils and four credits in General Bacteriology. Emphasis on chemistry has been evident through the years in the various curricula in Soils.

The current generalized curricula in Soils are presented in Table 3 where a comparison is made with the curriculum proposed by a committee on Training Soil Scientists of the Soil Science Society of America.*

Florida Curriculum I was planned as a terminal program for the student who does not intend to pursue advanced study in Soils. Curriculum II was planned for those who are interested in research or teaching in Soils and expect to enter Graduate School. The latter program at Florida compares very favorably with the minimum requirements outlined by the National Society.

The Soils Department offers courses in General Soils, Soil Management, Soil Fertility, Tropical Soils, Soil Microbiology, Fertilizers, Soil Classification and Survey, and Soil and Water Conservation at the under-graduate level. Many of these are taken by students majoring in other departments while the General Soils is a requirement of all students in the College of Agriculture as well as students in Forestry and Landscape Architecture. Therefore, the Soils Department functions in an important role as a service department in the College, while at the same time having a fair number of graduates with a major in Soils. During the period 1939 to 1959, 90 students have majored in Soils in the College of Agriculture at the under-graduate level.

During the past 20 years, 29 Masters degrees have been awarded by the Department. The majority has been thesis degrees with a limited number of non-thesis or Master of Agriculture degrees. The former were in the areas of fertility, chemistry, microbiology or soil physics while the latter were in general soils.

*Soil Science Society of America Proceedings 21: 122-123. 1957.

TABLE 3.—GENERALIZED UNDERGRADUATE CURRICULA IN SOILS AT THE UNIVERSITY OF FLORIDA COMPARED WITH THE MINIMUM REQUIREMENTS PROPOSED BY SSSA

Fla.-I	Fla.-II	Course	Proposed by SSSA
Semester hrs.			Semester hrs.
17	24-35	Chemistry, Physics, and Mathematics	42
14	21	(Chemistry	18
0	0- 8	Minimum (Physics	6
3	3- 6	(Mathematics	9
8	8	English	6
8	11	Botany (Including Physiology)	8
0	3	Geology	3
0	3	Bacteriology	3
20	22	Soils*	12

*College of Agriculture, University of Florida requires 20 hours for a major in any Department.

In 1951, the Department was granted permission to offer the Doctor of Philosophy degree. The first Ph.D. degree was awarded in 1955 and a total of six have been awarded to date. Presently seven candidates are working toward the doctorate, three of whom expect to complete their requirements in the first half of 1960.

The undergraduate teaching staff in Soils has increased from two in 1939 to nine at the present time. Four of the nine are giving full time to instruction while the remainder divide their time between the College and Agricultural Experiment Station. Eight additional full time Station staff members are approved for supervising graduate students' research programs. This brings the undergraduate and graduate staff to a total of seventeen.

The physical facilities in the Soils Department were greatly improved when the Department moved into Dan McCarty Hall in 1956. Prior to this date, approximately one-half of the staff was housed in temporary buildings on campus and the classroom and laboratory space was inadequate. At present, all of the teaching staff is situated in individual offices in McCarty Hall. Adequate classroom space is available and well equipped laboratories for soil microbiology, soil fertility, soil chemistry and soil physics courses are provided. Much badly needed equipment has been obtained for advanced courses at both undergraduate and graduate levels.

A LOOK TO THE FUTURE

A strong shift toward graduate training in both departments is expected during the next decade. Total enrollment for the University has been predicted at 20,000 for the 1970's. If this figure is reached, between 70 and 80 students probably will be training in Agronomy and Soils. Approximately two-thirds of these will be at the graduate level.

Major interest among the graduate students in Agronomy will be in the areas of radiation genetics, weed control, and biometrics. Soils students will be using the electron microscope, radio-isotopes and other new and yet untried techniques for studying clay minerals, tropical soil characteristics and new fertilizer materials. Soil biology will become increasingly important with new approaches in the areas of "rhizosphere effect" and

microbiological interactions as control measures for nematode and other pests. Physical measurements in soils as related to water control, tillage practices and root development will expand.

Present facilities on the University campus can and will make these predictions real and it can be said with certainty, "the teaching of Soils and Agronomy will be encouraged and the character of the training will be improved on all levels of instruction."

TWENTY YEARS OF PROGRESS IN SOILS RESEARCH IN FLORIDA

Progress In General Soils Research, 1939-1959.

F. B. Smith[1]

INTRODUCTION

Progress made in soils research in Florida during the past two decades includes advancements in soil classification and soil survey, soil chemistry, soil microbiology, soil physics, and improvements in soil fertility and management. No attempt will be made to give details of specific investigations in these areas since time permits only a brief summary of the research highlights to show the tremendous growth in soil science and its contribution to Florida agriculture during this period.

The past 20 years are characterized by marked change, growth, technological development and social and economic upheavals. This Society, organized during the early months of 1939, presented its first program April 18, 1939 at the annual convention of the Florida State Horticultural Society at Hollywood Beach. The march of German soldiers across the Polish Corridor in the late summer of 1939 was the beginning of armed conflict that would soon involve many nations of the civilized world in war. There were 12 soil scientists devoting full-time to soils research. This year, land was acquired for the Vegetable Crops Laboratory. During the following two years before the United States was directly involved in World War II the Statewide Soil Survey Law had been enacted and the Range Cattle Station established. Experiment Station Technical Bulletins 340 (40) and 341 (49) were published. Data contained in these two publications served as a basis for the revolutionary progress made in soil fertility and management since that time.

The next four years, the war years, was a critical period. The Experiment Station program, including soils research, was completely reevaluated and emphasis was placed on research which had a direct bearing on the war effort. In spite of shortages of scientific personnel, equipment and materials, tremendous strides were made in Florida agriculture. New and far reaching results were reported on water control and the availability of phosphorus in Everglades peat (10, 36), and the deficiency of iron in soils for Tung (12).

The period from 1945 to the present was characterized by rapid growth and expansion, an exploding population, inflation, increased production, new crops, and, as always, a host of unsolved soils problems. The staff of soil scientists increased from 12 in 1939 to 44 in 1959. Some of the accomplishments in the main areas of soils research are presented.

SOIL CLASSIFICATION AND SURVEY

Detailed and reconnaissance soil surveys were completed for 20 counties in the state during the past 20 years. Soil survey reports are available for Alachua, Collier, Dade, Hillsborough, Manatee and Sarasota Counties. The

[1]Microbiologist and Head, Department of Soils, University of Florida.

reports for Escambia, Gadsden and Orange Counties are in process of publication in the Government Printing Office. Detailed surveys of two percent of the area of all other counties in the state not recently surveyed have been completed during the past two years and a generalized soil map of the state is being drafted for early publication. The field survey of Suwannee County will be completed this year. Soil survey work between 1939 and 1952 was cooperative between the Bureau of Plant Industry, Soils and Agricultural Engineering and the University of Florida Agricultural Experiment Station. Since 1952 the soil survey has been cooperative between the Experiment Station and the Soil Conservation Service. Many of the soil scientists are employees of the Soil Conservation Service. The Experiment Station now has four soil scientists devoting full-time to field survey, research and correlation.

The classification of soils depends upon the state of knowledge of soils. As more was learned about soils, changes in the classification and names of soil types have been necessary. For example, during the survey of Alachua County, it was apparent that many soils in the state formerly mapped as Norfolk were not typical Norfolk, even though they had many similar profile characteristics. A new soil series was established and the name of these soils changed from Norfolk to Lakeland. As knowledge of soils continues to grow, changes in the present scheme of classification will be necessary.

Notable progress has been made in the laboratory characterization of soil types as they have been identified and mapped. Gammon *et al.* (30) have made physical, chemical and spectrographic analyses on key types. Investigations on the mineralogy of the clay fraction of Florida soils by Fiskell and McCaleb (20) and Fiskell, *et al.* (19) show that the clays of some of the well drained soils are fundamentally different from most of those in the somewhat poorly drained to poorly drained areas. The principal clay minerals in the well drained soils are vermiculite, kaolinite and gibbsite whereas the clays of the less well drained soils of South Florida are dominated by montmorillonite and vermiculite. The clays of the well drained soils are strongly acid and have a lower ion exchange capacity than those of the poorly drained soils. Because of the enormous surfaces developed by clay as compared to sand, the importance of the clay fraction, small though it may be, cannot be overemphasized. Certainly fertilizer studies on Florida soils cannot be considered sand cultures.

SOIL CHEMISTRY AND PHYSICS

Monumental progress has been made in soil chemistry and physics in the past two decades. The discovery of cobalt deficiency as the cause of "salt-sickness" in cattle, a disease widespread in Florida 25 years ago, was aided by the spectrographic analysis of a mineral used in the treatment of the disease (2, 26). Becker, Erwin and Henderson (1) showed significant correlation between the incidence of this disease and the cobalt content of soils on which animals were pastured. This latter finding was made possible by a spectrographic method for cobalt determination in soils developed by Carrigan and Erwin (9).

Formerly, the determination of magnesium in soils was long, tedious and time consuming. Much time and effort has been devoted to modification, improvement and adaptation of the official method to soil analysis. Peech (41), Wilson and Wander (75), and Drosdoff and Nearpass (13)

found the procedures subject to many errors. With the development of synthetic resin ion-exchange materials and the spectrophotometric procedures for analysis, real progress has been made. Horn (34) recently made important improvements in the method for the determination of magnesium in soils and plant materials, making this determination a routine procedure.

Progress in the investigation of the potassium status of Florida soils was at a standstill until the development of flame photometry. Forsee and Erwin (25) working on organic soils and Gammon (27) working on sandy soils, developed routine procedures for the rapid determination of potassium in soils. The availability, retention and uptake of potassium by plants is now widely investigated and the potassium needs of crops has been determined for a number of soils.

Perhaps the most spectacular development in the field of methodology has been the use of the radioactive tracer technique. Comar and Neller (11) and Spencer (58) adapted the technique to study the factors affecting the fixation and leaching of phosphorus in Florida soils. Robertson, Neller and Bartlett (48) employed the technique to study the effect of lime on the availability of phosphorus in the soil and Harris, Bledsoe and Gilman (33) used it to study the utilization of soil and fertilizer phosphorus by corn. Yuan, Robertson and Neller (76) employed P^{32} in studies on the forms of phosphorus in different soils. Bledsoe, Comar and Harris (3) employed Ca^{45} and Thornton and Broadbent (67) used N^{15} in studies on the calcium and nitrogen nutrition of peanuts. An equally outstanding contribution to progress was that of Stewart and Leonard (62) on the chemistry of metal chelates and their application in the treatment of iron chlorosis of citrus.

Probably the most notable change in agricultural practice of economic importance has been the gradual recognition of the importance of soil reaction. The importance of correcting excess acidity of the soil in the conservation of fertilizer constituents has been shown by a number of investigators (43, 37, 57, 69, 70, 71, 28). Stewart and Leonard (63) found that iron chlorosis of citrus was commonly associated with strongly acid soils. Eno and Blue (17) found a low efficiency of anhydrous ammonia and urea in strongly acid soils. Volk (68) found that soils so acid in reaction as to prevent nitrification caused an abnormal growth condition in potatoes and marked reduction in yields. Eddins, McCubbin, Gammon and Volk (14) found that whiptail in cauliflower, caused by a deficiency of molybdenum, was associated with soil acidity and that adjusting the soil pH to 5.5 usually corrected the deficiency.

The importance of basic research on soil moisture is emphasized when one considers the acreage of poorly drained soils in the state and the need for their better utilization, the conservation of water resources, removal of excess water and the need for supplemental irrigation. A soil physicist was added to the staff in 1950. Research on soil moisture constants was initiated and significant findings on soil moisture measurements have been reported (32, 35, 47).

SOIL MICROBIOLOGY

Progress in soil microbiology has been no less spectacular and far-reaching in its effects on Florida agriculture than in other branches of soil science. Reference to the Annual Reports of the Florida Agricultural Ex-

periment Station and journal articles by members of the Station staff shows the literature replete with accounts of investigations in this field. The discovery of nutritional leaf roll in potatoes (69, 74) stands out as a major accomplishment. Important contributions have been made in studies on microbial populations (4, 16, 17, 31, 50, 51, 52, 64), effects of insecticides, fumigants, pesticides, fertilizers, temperature and moisture (18, 39, 54) on microbiological action in soils. Investigations on legume inoculation have emphasized its importance, resulted in improved efficiency of cultures, and firmly established the practice (53, 55, 56, 65). Significant progress has been reported in the study of biological interactions (66) and a measure of microbial control or regulation other than sterilization has been achieved (15).

SOIL FERTILITY AND MANAGEMENT

The soils of Florida, for the most part, are inherently poor in the major plant food elements and deficiencies of one or more of the minor elements are known to occur on many soil types for certain crops. Tremendous strides have been made in the production of all crops as information on the use of boron, copper, manganese, zinc and other minor elements has become available during the past two decades. In 1939 the state average yield of corn was 8.2 bushels per acre, in 1958 it was 26, with yields of 60-70 bushels per acre not uncommon. In 1942 the average yield of oranges was 1.5 boxes per tree, and in 1958 it was 3.3 boxes per tree. These facts present strong evidence that results of research in soil fertility and management has been effective. The problems have been largely peculiar to the soils of the state and knowledge gained from soil fertility investigations in other states has often been of little value.

One problem common to the crop production specialist as well as the soil scientist in which outstanding progress has been made will be reviewed in some detail. Reference is made to the use of soil tests as an index of the fertility needs of the soil. In 1939 at the organizational meeting of this Society, Carrigan (8) discussed the promise of spectrographic procedures, conventional chemical analysis and the use of field kit tests in soil analysis and emphasized the need for caution in the interpretation of results. He pointed out that the amount of phosphorus extracted by different solvents on a given soil might be widely different but the absolute magnitudes of the amounts is unimportant provided the test shows significant differences between levels of nutrient concentrations in the soil. From this standpoint one extractant is equally as satisfactory as any other. To be of value the soil test must give results which correlate with the fertilizer needs of the soil. Since that time, Volk, Bell and Winsor (72), Neller and Forsee (38), Forsee (21), Spencer and Beckenbach (60, 61), and Breland (7) have reported on extensive studies of quick test methods. Conventional laboratory methods of soil analysis have been developed by Forsee (23) and Breland (6) and spectrophotometric procedures are now widely used.

A real effort has been made to correlate the results of soil tests with response to applications of fertilizers in field experiments and the records show that much has been accomplished. Peech (42) made correlation studies on the magnesium requirement for seedy grapefruit and found that a soil should contain 30 pounds of magnesium per acre to prevent magnesium deficiency.

Volk, Bell and McCubbin (73) concluded that when the nitrate con-

tent of the soil dropped below 15 pounds per acre of nitrate nitrogen, a side dressing of nitrate was needed for maximum production of cabbage.

Neller and Forsee (38), Forsee (22, 23, 24), and Forsee and Erwin (25) reported that maximum yields of celery on Okeelanta peaty muck required P and K levels by soil tests of 50 and 250 pounds per acre, respectively. Beans showed a response to 60 pounds per acre of potash where the soil test value was 40-60 pounds of K_2O per acre, but no response to phosphorus if the soil contained 6-18 pounds per acre of P_2O_5. Cabbage gave no response if the soil contained 30-275 pounds per acre of potash and 5-15 pounds per acre of P_2O_5. Corn on Everglades peaty muck showed yield response to increasing levels of potash in the soil up to 70 pounds per acre, by soil tests using 0.5 N acetic acid soluble potassium, but no response was obtained to soil levels of phosphorus in excess of 10 pounds of P_2O_5 per acre. For maximum yields of iceberg lettuce on Everglades peat, the level of water-soluble phosphorus should be 5-7 pounds per acre and the level of potassium should be 100-150 pounds per acre.

Spencer and Beckenbach (59) reported a nitrogen level of at least 30 pounds per acre and a potassium level of 95-100 pounds per acre should be maintained for tomatoes on Leon, Bradenton, Manatee and Parkwood soils.

Gammon *et al.* (29) found potassium deficiency in clover when available potassium in the soil was reduced to 50-70 pounds per acre.

Blue and Gammon (5) obtained excellent correlation between yields of clover and grass and soil test values for extractable phosphorus. They concluded that an application of 40 pounds per acre of phosphate would be necessary if acid ammonium acetate-soluble phosphorus was 5 pounds per acre or acid ammonium fluoride extractable phosphorus was 150 pounds per acre.

Pritchett (45) found significant positive correlation between levels of phosphorus and potassium, as determined by soil tests, and crop yield response to fertilization of general field crops on the principal soil types of North Florida.

In recent years considerable interest has developed in forest fertilization. Since vast acreages in Florida are devoted to forests, the question is an important one. Little information is available on the subject. However, considerable research on fertilizing trees has been initiated (46). An investigator contemplating work in the field is faced with the question of where and how to begin. Pritchett and Robertson (44) have made an important contribution to this end with adapted field plot techniques.

This report of 20 years progress in soils research naturally leads one to speculate on what progress the next 20 years will bring. Since no one predicted 20 years ago that television, jet aircraft, atom bombs, inter-continental missiles, and rockets orbiting the sun and moon would be commonplace now, perhaps it would be wise to end this report without making a prediction. However, it appears certain that all the soils problems will not be solved during the next 20 years.

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Soil Morphology and Classification

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While there are some who will always yearn for "the good old days," those of us who are concerned with soil morphology and classification will certainly not be among them. For in this field of research, there have been many changes during the past twenty years—most, if not all, for the better.

"Morphology" is a term which refers to the physical description of an object. When applied to soils, morphology means nothing more than a description of the soil body, its appearance, features, and general characteristics as expressed in the soil profile. To be able to properly describe the morphological features of a soil we must note the following:

(1) The number and arrangements of the soil horizons.
(2) The thickness of the various horizons.
(3) The color of the various horizons.
(4) The texture of the various horizons.
(5) The structure of the various horizons.
(6) The consistence of the various horizons.
(7) The reaction of the various horizons.
(8) The geology of the parent material.

In addition to these "internal features" of a soil, proper cognizance of the

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soils relationship to certain "external features" should also be noted. Most important of these are land form, relief, and drainage.

Changes in either definitions, descriptions, and/or methods have not been made in each and every one of these morphological features during the last two decades. For example, we still note the number and relative arrangement of the horizons within a soil profile counting from the surface downward. We also measure the thickness of each horizon in inches as in the past. Modifications and improvements have been made, however, in most of the remaining morphological features and can be summarized as follows:

COLOR

The first real breakthrough in soil color designation occurred in 1941 when the soil scientists set up some preliminary color standards based on matching soils with Munsell color chips (6). Prior to this time, soil color was mostly described by the person viewing the soil as he saw it and, in most instances, failed to convey the same visual image to another person who had only the written description.

Modifications and improvements of this Munsell system have been made until now we have a Soil Color Book (4) by means of which we can match and describe any soil color very exactly. Then, any other person having a similar color book and reading of the soils so described can know precisely their colorations. This color book consists of some 200 differently colored chips and includes only that portion of a much larger Munsell Color chart that is needed for soil colors. These color chips are systematically arranged on cards in a loose-leaf notebook according to "hue," "value," and "chroma." "Hue" is the dominant spectral color and is related to the dominant wavelength of light. "Value" refers to the relative lightness or darkness of a color and is therefore a function of the total amount of light. "Chroma" is a term which refers to the relative purity of the spectral color as opposed to grayness.

The use of this book to describe soil color is quite simple. A small portion of the soil, usually in the moist condition, is matched as closely as possible to one of the color chips and the color name of that chip would then be the color name of the soil. Since several color chips may have the same color name, it is sometimes desirable to also include immediately after the color name of the soil the Munsell notation of the matching chip. This additional information is used to supplement the color names wherever greater precision is desired, as a convenient abbreviation in field descriptions, for expression of the specific relations between colors, and for statistical treatment of color data. If used on an international scale, this Munsell notation would be especially useful as no translation of color names would be needed.

The color of each and every soil horizon can thus be accurately described. Should any horizon be made up of more than one soil color, the color of each different mottling would be obtained by the same matching procedure and their degree of contrast and abundance would be properly noted.

TEXTURE

The mineral particles of the soil are classified according to size into sand, silt, and clay. The particle sizes of each of these mineral groups

range between certain limits which, according to the U. S. D. A. system for the designation of soil separates, have been adopted as follows:

Name of Separate	Size (in mm. diameter)
Very coarse sand	2.0 -1.0
Coarse sand	1.0 -0.5
Medium sand	0.5 -0.25
Fine sand	0.25 -0.10
Very fine sand	0.10 -0.05
Coarse silt	0.05 -0.005
Fine silt	0.005-0.002
Clay	less than 0.002

The only change within the past twenty years has been in the nomenclature of the 2.0 to 1.0 mm. diameter size fraction. Prior to 1947 it was designated as "fine gravel," but now it is known as "very coarse sand."

According to the proportion of the different sized mineral particles that a soil may contain, we designate its texture by means of a soil triangle and give it a soil class name. During the early development and study of soils many changes were made in the soil triangle in an attempt to obtain better correlation between the identification of soil texture in the field and the actual percentages of sand, silt, and clay as determined in the laboratory. This seems to have finally been accomplished as there has been only minor changes in the soil triangle within the last twenty years. These occurred in the early 1940's when "sand" and "loamy sand" were slightly modified and "silt" was added to increase the number of soil classes from eleven to twelve.

STRUCTURE

Soil structure refers to the arrangement or grouping of the individual soil grains or particles into aggregates or clusters. Soil structure deals with the size, shape, and durability of natural aggregates resulting from variation in the forces of attraction within a soil mass. Its influence on soil management and the resultant productivity is very great. The permeability of both water and air especially in the finer-textured soils is directly dependent upon the type of soil structure.

Johnson (2) in 1877 was probably the first to prove experimentally the relationship of several soil properties to structure. Since then many investigators (1, 3, 5) have studied and classified soils into structural units often using rather strange sounding words. Some of these, which have since been abandoned, included pulverulent, nutty, schistose, foliated and squamous.

Today, there are only four recognized primary types of structure. They are:

(1) *Spheroidal*, with particles arranged around a point and bounded by curved or irregular surfaces; of which the relatively non-porous aggregates are termed "granular," and the very porous ones "crumb."

(2) *Blocklike*, with particles arranged around a point and bounded by flat surfaces, called "angular blocky," or by rounded faces, called "subangular blocky."
(3) *Platy*, with particles arranged around a plane, generally horizontal, and usually parallel to the soil surface.
(4) *Prismlike*, with particles arranged around a vertical line and bounded by relatively flat vertical surfaces, of which "prismatic" refers to aggregates having flattened tops and "columnar" to those with rounded caps.

In addition, two other terms—"single-grain" and "massive" are used in speaking of soil structure to describe conditions in which there is either no aggregation of soil particles, or the aggregates are so large that their size or shape cannot be easily determined.

The soil aggregates are further classified as to size—with terms such as "very fine," "fine," "medium," "coarse," and "very coarse" being used—and also to degree of development with terms like "structureless," "weak," "moderate," and "strong."

CONSISTENCE

Soil consistence refers to the relative mutual attraction of the soil particles to one another within the whole soil mass and to their resistance to deformation or rupture. It deals with the strength and nature of the forces of attraction within a soil and varies considerably with moisture content.

In the past a number of terms—including "brittle," "crumbly," "dense," "elastic," "fluffy," "mealy," "mellow," "spongy," "stiff," "tough," and others— have often been used in describing the consistence of soils. These are all quite common words and are still used at times by the layman. However, a more precise terminology has been outlined in the Soil Survey Manual (7) which describes soil consistence as follows:

(1) *Consistence when dry*, using the terms "loose," "soft," "slightly hard," "hard," "very hard" or "extremely hard."
(2) *Consistence when moist*, using the terms "loose," "very friable," "friable," "firm," "very firm," or "extremely firm."
(3) *Consistence when wet*, using the terms "nonsticky," "slightly sticky," "sticky" or "very sticky" for the varying degrees of stickiness, and also the terms "non-plastic," "slightly plastic," "plastic" and "very plastic" for varying degrees of plasticity.

At times a cementation of soil material may occur that results in a brittle hard consistence that is altered little if any by moisture. Such conditions can usually be best described by using the terms "weakly cemented," "strongly cemented," or "indurated."

REACTION

Soil reaction refers to the degree of acidity or alkalinity that may be present in any given soil. Early field workers distinguished roughly between acid and alkaline soils by the use of either litmus paper or phenolpthalein. They also treated the soil with dilute hydrochloric acid, a tech-

nique still used by soil surveyors today to test for the presence of free carbonates in the various horizons of a soil.

Since then, better field methods, based upon improved laboratory procedures, have become available. Most soil reaction studies in the field utilize various indicators or dyes that have different colors at different pH values. Where more precise determinations are required, especially where salts are likely to interfere; a field pH meter may be used or the soil samples may be taken to the laboratory.

Once the pH of each soil horizon is known, the correct terminology can be selected from the following table (7):

	pH		pH
Extremely acid	Below 4.5	Neutral	6.6-7.3
Very strongly acid	4.5-5.0	Mildly alkaline	7.4-7.8
Strongly acid	5.1-5.5	Moderately alkaline	7.9-8.4
Medium acid	5.6-6.0	Strongly alkaline	8.5-9.0
Slightly acid	6.1-6.5	Very strongly alkaline	Above 9.0

LAND FORM

Land form is conceived as a three-dimensional portion of the landscape resulting from the forces of its environment and is thus an essential part of a soil. Different land forms may and sometimes do exert a genetic influence upon their associated soils causing different soil profiles to be developed. Although variation in land form by itself is not always a sufficient basis for differentiating between soil series, it is usually associated with other differentiating characteristics.

Soil scientists are giving increasing recognition to the importance of land form in soil classification and interpretation. Materials in terraces and other formations of differing ages and origins may appear to be similar in the field, yet have significantly different compositions. A study is presently being made here in Florida to determine whether or not there is any relationship between some finer-textured horizons of soils occurring on different marine terraces. This research will contribute valuable information pertinent to soil genesis and aid in the nomenclature of these horizons in the soil profile.

RELIEF

Relief is often used broadly to indicate differences in elevation within an area or perhaps only the difference between the highest and lowest altitude of an area. A more precise concept of relief, however, implies relative elevation and thus pertains to the inequalities of a land surface. As such, an integral part of relief is "soil slope," a term which refers to the incline of the surface of the soil area.

There are two recognized types of slopes (1) "single slopes," which are inclined primarily in one direction and (2) "complex slopes," which occur more commonly on rolling terrain and are thus inclined in many directions. Until approximately five years ago, complex slopes were used more in Florida than single slopes. Since then the trend has been reversed and all

slope terminology is now expressed in single slopes. The classification of slopes presently used in the State is as follows:

Slope	Range in Percent	Single Slope Name
A	0-2	Level
B	2-5	Very Gently Sloping
C	5-8	Gently Sloping
D	8-12	Sloping
E	12-17	Strongly Sloping
F	Above 17	Moderately Steep and Steep

DRAINAGE

Soil drainage refers to the rapidity and extent of the removal of water from the soil both by surface runoff, termed "external drainage," and by flow through the soil to underground spaces, termed "internal drainage." A rather complete revolution of all drainage terminology and definitions has occurred within the past ten years. Surface runoff has been divided into six classes ranging from "ponded" (where none of the water escapes) through the drainage terms "very slow," "medium," "rapid," to "very rapid" (where a very large part of the water added to the soil moves rapidly over the soil surface and only a very small part goes through the profile). In a similar manner, six classes of internal drainage are also recognized. These range from "none" (where no water passes downward through the soil profile) through the same named terms listed above (but with different definitions) to "very rapid" (where the rate of water movement through the soil profile is very fast).

According to the degree by which water is removed from a soil, it may be placed in one of the following drainage classes (7):

(1) *Very poorly drained*, where water is removed so slowly that the water table remains at or on the surface the greater part of the time.
(2) *Poorly drained*, where water is removed so slowly that the soil remains wet for a large part of the time.
(3) *Somewhat poorly drained*, where water is removed from the soil slowly enough to keep it wet for fairly long periods but not all of the time.
(4) *Moderately well-drained*, where water is removed from the soil at a rate such that the profile is wet for a small but significant part of the time.
(5) *Well-drained*, where water is removed from the soil readily but not rapidly.
(6) *Somewhat excessively drained*, where water is removed from the soil rapidly.
(7) *Excessively drained*, where water is removed from the soil very rapidly.

EROSION

As water or wind moves over the surface of the soil, some of the particles are dislodged and transported from one place to another. Depending upon the amount of this soil removal, we classify soils as having different degrees

of erosion. Actually, there are two different kinds of erosion—*"Natural" or "Geologic" erosion* and *"Accelerated" erosion*. Natural erosion is the wearing away and removal of soil materials which normally occurs with the native vegetation present on the landscape. Accelerated erosion is that which is speeded-up over that which is normal for that soil and is usually due to the mismanagement of the soil by man. This latter type of erosion may result from exposure of the soil by such practices as burning, excessive grazing, forest cutting, and tillage—any of which destroys or weakens the vegetation.

Most of the soils in the State are uneroded or shows only slight accelerated erosion. Small areas in the sloping landscape, dominantly in the finer-textured soils of North Florida, show moderate erosion with even smaller areas exhibiting severe and gully erosion. Most conditions of accelerated erosion in Florida can be included in one of the following eroded classes:

(1) *Uneroded and or slightly eroded class*, to indicate an area which has 75 percent or more of the surface soil remaining. The plow layer of soils is within the A horizon of thick surface soils; or the plow layer of soils with thin A horizon retains approximately the same physical properties and characteristics resulting from the initial stirring and mixing of the A horizon and the underlying horizon. A few rills or soil drift may occur in some areas.

(2) *Moderately eroded class*, to indicate an area where soil loss or truncation has occurred and approximately 25 to 75 percent of the original A horizon or surface soil remains over most of the area. Ordinary tillage implements reach through the remaining A horizon, or well below the depth of the original plowed layer in soils with thin A horizons. Generally, the plow layer consists of a mixture of the original A horizon or surface soil (plow layer) and underlying horizons. Ocasional shallow gullies or blowouts may be present.

(3) *Severely eroded class*, to indicate an area where soil loss or truncation has taken place to the extent that all or practically all of the original plow layer, surface soil, or A horizon has been removed. The plow layer consists essentially of materials from the B or other underlying horizons. Less than 25 percent of the original plow layer or A horizon remains on most of the areas; and commonly a part or all of the B horizon or underlying horizons may have been lost from some of the areas. Shallow gullies or blowouts are common on some soil types.

In addition, gullied lands or blown-out lands have more than 40 percent of the delineated area occupied by moderately deep or deep gullies or blowouts. Gullied lands or blownout lands are considered as a miscellaneous land type and not as an erosion phase. An increased growth of vegetation will retard the movement of soil particles by sheet, gully or wind erosion.

CLASSIFICATION

Classification has been defined as "an orderly arrangement of knowledge." As we study and learn more about the morphology of various soils, we tend to group soils together which have somewhat similar characteristics. Since the earliest days of agriculture, many different systems of soil classification has been proposed. The one used today by soil scientists in this

country is essentially the one devised by Marbut in 1928, modified by Kellogg in 1938, and only slightly changed since then. However, a new scheme of soil classification by the soil survey staff of the U. S. D. A. in cooperation with the various state agricultural experiment stations is being studied, and its likelihood for adoption is very good. Should this happen, the lower units of classification such as soil series, type, and phase would remain unchanged and only the higher categories would be affected.

The application of the morphological study of soils and their classification is perhaps best exemplified in the soil survey program within the various states. A soil survey is an inventory of the soil resources of an area. It is a systematic examination of the soils in the field and laboratory. The soils are described and classified into series, types, and phases. The boundaries of the different soils are located in the field and are plotted on maps in relation to the location of roads, streams, lakes, houses, and other physical features of the landscape. Slope of each soil mapped and the degree of accelerated erosion, if present, are noted and this information is plotted on the base map which is most always an aerial photograph. At the present time the published soil map consists of soil areas delineated on a photographic background. The location of any specific area can thus be found quickly and with great accuracy by reference to one or more of the above listed features of the landscape.

A report is prepared and published together with the soil map. The report gives general information about the area, descriptions of the various soil units, their use-suitability and productivity under different systems of management. When a soil survey is completed for an area, little if any additional field work is required for making specific land classifications for soil management practices, crop adaptability, land-use capabilities, erosion hazard, grassland management, forest management, water control, research planning, tax assessments, highway construction, natural resources, health and sanitation measures, and many other interpretative groupings.

Some twenty years ago, if a county in Florida desired to have a soil survey made of their area, that county was required to pay for part of the cost. This usually amounted to the actual expenses of the men and trucks used in the survey operations. In 1941 the State Legislature passed a law which provided an appropriation for surveying the soils in the State of Florida. The present appropriation permits the employment of four State men in the soil survey program. In addition, there are about sixteen men employed by the Federal Government who are also aiding in this work, so that no money is required now from a county for a soil survey. All surveys in the State are now conducted as a cooperative program between the Florida Agricultural Experiment Station and U. S. D. A. Soil Conservation Service.

During the years from 1943 to 1947, an important change took place to cause a separation of those soils having thick sand mantles from those having clayey materials at shallow depths. Prior to this time depth to a finer-textured layer was denoted in the soil type name which was not necessarily the texture of the surface soil. Today, this is no longer true and a soil type name now truly indicates the texture of surface soil added on to the series name. This change caused most of the soils in Central and South Florida to become fine sands, medium sands, or coarse sands; while in West Florida the predominant soils are now classified either sands, fine sands, loamy sands, and loamy fine sands. Only a few soils have sandy loams or finer texture.

An arbitrary depth of thirty inches was taken to separate somewhat similar soil series, some of which had sandy materials to greater depths from others which had clayey horizons within that depth. These separations were made primarily because the presence or absence of a fine-textured layer at this depth seemed to affect the moisture regime in soils and also the root growth of many plants. Due to this decision, some of the related soil series now mapped in Florida include:

Soil Series having clayey materials* below 30" (or absent)	Soil Series having clayey materials* within 30 inches
Lakeland	Norfolk
Eustis	Ruston
Americus	Red Bay
Huckabee	Kalmia
Independence	Cahaba
Gainesville	Hague
Arredondo	Zuber
Kanapaha	Blichton
Jonesville	Hernando
Adamsville	Sunniland
Pompano	Felda
Delray	Manatee
Plummer	Rains
Rutlege	Portsmouth

*Denotes soil horizons having a sandy loam or finer texture.

During the past 20 years, approximately 60 percent of the total land area in Florida has been surveyed. Modern detailed soil surveys have been completed for Alachua, Collier, Dade, Manatee, Hillsborough, Sarasota, Escambia, Orange, and Gadsden Counties. The reports and soil maps are available for nearly all of these counties from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Field work is now in progress for the surveys in Suwannee, Washington, and Holmes Counties. Soil maps are also being made of individual farms in most of the other counties.

Reconnaissance soil surveys have been completed of counties in the Everglades Region and in the Kissimmee and Upper St. Johns Valleys. Soil maps are still available for the Everglades Region from the bulletin room at Florida Agricultural Experiment Station and those for the Kissimmee and Upper St. Johns Valleys can be studied at the offices of the county agricultural agents in the various counties.

Approximately three hundred and twenty soil types have been mapped in Florida to date. Undoubtedly additional soil types will be recognized in future surveys in other counties. A generalized soil map of the state is now in progress and should be completed in another year.

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Soil Microbiology In Florida, 1939-1959

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INTRODUCTION

Official recognition of Soil Microbiology by the Florida Agricultural Experiment Station was given in 1937 when the first Soil Microbiologist position was filled. Prior to this date, work in soil microbiology at the University of Florida had been largely confined to nitrogen fixation with notable contributions being made by Carroll (5) on cross-inoculation groups in the genus *Rhizobium* and by Mowry (27) on nitrogen fixation by *Casuarina*.

Beginning with the fiscal year 1938, four projects in the field of soil microbiology were approved by the Agricultural Experiment Station. Some of these have been completed, others revised and new projects have been added throughout the past two decades. This paper brings together most of the major contributions resulting from the research on this important segment of soil and crop management.

SOIL MICROBIOLOGICAL POPULATIONS

Among the early research projects approved for soil microbiology was one providing for an investigation of the types and distribution of microorganisms in the soil. This was a productive project and much interesting data was collected.

Smith and Gall (36) showed that there was a characteristic flora for the different soil types despite the large interactions between soil types and temperature, rainfall and moisture content of the soils. There were larger average numbers of bacteria in the soils after the mean monthly temperature dropped below 70 F. Generally molds and actinomycetes were more numerous in soils under rotations including cover crops than in soils continuously cropped to corn and peanuts. A Leon fine sand, the most strongly acid of the seven soils studied, contained the smallest average total number of organisms; whereas, a Gainesville fine sand, the least acid of the soils under study, contained the largest average total number of organisms.

Smith (33), and Smith and Ellis (35) reported on the algal flora of some Florida soils. In these preliminary studies, 17 genera of algae were observed in six soil types. *Chlorococcum humicola* (Naeg.) Rab., was the

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dominant species at depths of four or five inches in all soils and at all sampling dates. No other single species was generally observed in the several soils at different depths and different times of sampling.

More recently, Eno and Ford (17) reported interesting observations regarding the vertical distribution of microorganism populations in the soil profile. Studies were made to a depth of 10 feet in several soils under citrus culture. The nitrifying bacteria decreased from 1,000,000 or more per gram in the 0-5 inch layer to less than 100 per gram below four feet. Fungi and bacteria progressively decreased with depth and were approximately 15 percent of the surface numbers at 8-10 feet with bacteria exceeding fungi to a depth of 6 feet. Nematodes progressively decreased with depth, none being observed at six feet and very few below 20 inches.

These findings differed somewhat from those obtained by Blue, Eno and Westgate (4) in studies of a Leon fine sand that had been in vegetable production for approximately 50 years. In the latter study, fewer organisms were found at the 9-12 inch depth with higher numbers in the surface and below 12 inches. This horizon of low population corresponded to the position in the profile with lowest organic matter content and smallest quantity of nutrients, above and below this level numbers fluctuated with nutrient level. The surface population was strongly influenced by fertilizer applications and the lower depth by underground irrigation water. However, despite almost continuous saturation, this zone had increased numbers of microorganisms with increasing nutrient concentrations, particularly potassium and nitrates.

Thames (42) examined a total of 762 soil samples for the presence of plant parasitic nematodes. The samples were collected from cultivated and uncultivated sites. Thirty species of the most common plant parasitic nematodes known in Florida were found in soils that had not been cultivated. However, the populations were much lower in the uncultivated than in cultivated soils.

Good (24) and Good and Thornton (25) reported relative changes in populations of sting nematode on six winter legumes. Increases occurred on hairy vetch and crimson clover while populations decreased on bitter blue lupine. There was no change in populations of this parasite in soils where Hubam sweetclover, sweet yellow lupine or Austrian winter pea were growing.

SYMBIOTIC NITROGEN FIXATION

As early as 1941, fertility studies (1) had pointed to the need for calcium, potassium and phosphorus for successfully establishing clover pastures in Florida. This work also revealed the effect of various sources of these elements on nodule development of the legumes. Thus, with clovers coming into the pasture program, the need for research on many problems concerned with the inoculation of these crops became apparent.

Factors affecting the longevity of nodule bacteria were studied by Thornton (43). *Rhizobium trifolii* were recovered from pots of variously treated Leon fine sand and stored for eleven and twenty months only where the treatment maintained the soil reaction at pH 6.2 or above. In addition to $CaCO_3$, potassium and phosphorus were also effective in extending the survival time of the organisms.

Subsequent field studies by Smith *et al.* (34) indicated that successful initial inoculation of the *Trifolium* species could be expected at pH 5.2 or

above while the bur and sweetclovers required pH 6.3 or above. It was also observed in these studies that rates of inoculation in excess of that normally recommended gave superior results.

Numerous experiments (21, 23, 34), testing many strains of nodule bacteria for clovers, bur clover, sweetclover, lupine, soybean, lima bean, peanuts and hairy indigo, have clearly demonstrated the economic value of selecting cultures that are superior in nitrogen fixing ability. In many instances yields of herbage and total nitrogen content have been increased two fold by using a superior strain of rhizobia. In other cases the increase may not have been as dramatic, but in most trials an economic increase in return was obtained.

Through the use of the tracer technique and stable isotopic nitrogen, it has been possible to study the nitrogen nutrition of legumes. These studies by Thornton (44, 45) and Thornton and Broadbent (49) showed that the amount of nitrogen fixed by inoculated legumes was directly related to the available nitrogen supply in the soil. As the supply of combined nitrogen in the soil was increased, the amount of atmospheric nitrogen fixed by nodule bacteria decreased. However, it was demonstrated that although an adequate supply of available nitrogen existed in the soil, some nitrogen was fixed. Small seeded legumes such as clovers benefited more from early light applications of combined nitrogen while large seeded legumes such as soybeans responded more favorably to heavier mid-season applications.

Thornton *et al.* (48) isolated several fungi and streptomyces from the surface of the roots of sweetclover and studied them for possible antagonistic effect toward *Rh meliloti*. Six cultures of the streptomyces and two fungal cultures showed antibiotic properties toward the *Rhizobium* when they were grown together on agar plates. Further research is needed to determine the economic implications involved in this phenomenon.

THE EFFECT OF PESTICIDES ON SOIL MICROORGANISMS

Toxicants of many kinds are frequently used to control undesirable soil organisms. Unfortunately, most of these compounds are non-selective in their action against the microfauna and microflora in the soil; consequently, beneficial organisms are affected to varying degrees.

Fumigants—Smith (40) studied the effects of D-D and EDB on nitrogen transformations in a Leon fine sand and the effects of these compounds as well as chloropicrin were studied in an Arredondo fine sandy loam. His results were in agreement with those reported by Spencer and Jack (41) who used chloropicrin, EDB and methyl bromide in a Manatee fine sandy loam (heavy phase). In all instances an accumulation of ammonia and a reduction in nitrate production occurred. However, the effects were transitory and the soils eventually returned to normal.

Soil temperatures of 35 F. or lower at the time of treatment and immediately following apparently reduced the rate of volatilization of D-D as indicated by root injury to celery plants. However, Thornton (16) noted little variation in the effect of D-D on nitrification as a result of soil temperature at time of application.

Overman and Burgis (29) found Crag Mylone, when used at 100 to 200 pounds per acre, to be an effective fungicide at the higher rate of application and it gave adequate control of nematodes at both rates. There seems to be some question regarding the effects of this compound on nitrification.

Insecticides—The effects of DDT, chlordane and aldrin on the flora of Arredondo fine sand were investigated by Horn (26) and Ross (31). Additions of 5, 30, 60 and 120 ppm. of DDT increased, although not directly proportional, the relative numbers of bacteria, fungi and actinomycetes; it stimulated ammonification and had no significant effect on nitrate production. Chlordane, applied at 12, 25, 50 and 100 ppm., increased the relative numbers of bacteria, reduced the fungi and had no significant effect on the actinomycete population; this material did not affect nitrification or ammonification significantly. Aldron, at 1, 2, 4, and 25 ppm., did not effect the bacterial population but did significantly increase the relative numbers of actinomycetes. It had little effect on the numbers of fungi. Aldrin did not effect nitrification or ammonification. In general, the effects of all three of these insecticides on the soil population were very moderate.

The effects of heptachlor, chlordane, methoxychlor, lindane, aldrin, toxaphene, dieldrin, TDE, DDT, and BHC on soil microorganisms and Stringless Black Valentine Beans were studied by Eno and Everett (16). These insecticides were applied to Arredondo fine sand at 12.5, 50 and 100 ppm. of the active ingredient and maintained in pots in a greenhouse throughout the study. The first crop of Stringless Black Valentine beans, planted 2 weeks after treatment, showed that BHC decreased germination; all other insecticides increased germination or had no effect. Root and top weights were decreased by chlordane, lindane, aldrin, dieldrin, TDE, DDT, and BHC. Only top weights were reduced by methoxychlor. Heptachlor and toxaphene had no effect on growth. Germination and root growth of a second crop of beans, seeded eleven months after application of the insecticides, were not affected; top growth was significantly reduced by lindane, aldrin, TDE, DDT, and BHC. Microbial data, obtained one month after application of the insecticides, indicated that they had no effect on the numbers of bacteria in the soil. Dieldrin increased the numbers of fungi; all others had no effect. Carbon dioxide evolution was increased by toxaphene, dieldrin, TDE, DDT, and BHC; the others had no effect. Nitrate production was decreased by heptachlor, lindane, and BHC; increased by toxaphene, TDE, and DDT; and unchanged by the others. Sixteen months after application of the insecticides no significant changes occurred in numbers of fungi and bacteria or carbon dioxide evolution. Nitrate production was reduced by DDT and BHC. Based upon the measurements made in this study, the growth of Stringless Black Valentine beans was influenced more than the microorganisms by the presence of insecticides in the soil. Until more specific information on microbial responses to these materials has been obtained, it appears that toxicity of higher plants will be the earliest warning of phytotoxic amounts of chlorinated hydrocarbon insecticides in the soil.

Eno (12) has recently reviewed the subject of insecticides and the soil.

COMPOSTS AND COMPOST INOCULANTS

There are two general ways in which compost material may become inoculated with organisms active in decomposition. They are (a) chance inoculation and (b) deliberate inoculation. In the vast majority of cases, chance inoculation is sufficient to initiate the process of decomposition in normally composted plant and animal materials. Despite this fact, inoculants in many forms are deliberately added. Soil and various manures are two of the most common materials added, in part, for this purpose. How-

ever, more than the introduction of living organisms is accomplished by the addition of soil and manure for both lend desirable chemical and physical properties to the compost. In addition to naturally occurring substances, such as soil, certain prepared inoculants are also available. These products are alleged to contain a select group of organisms or other substances highly efficient in the breakdown of organic materials such as occur in composts. When used, these commercial preparations often constitute a major expense in the composting operation.

According to Thornton (47), probably the oldest known method of stimulating decomposition in the compost heap is through the use of animal manures. The composting of manure has been a favorite practice with gardeners throughout the world for centuries. It was common practice in the South to compost a mixture of cottonseed, manure, acid phosphate and kainit before applying it on the land.

Smith and Thornton (38) prepared composts consisting of pine needles and cottonseed meal, and pine needles and horse manure which were found to have temperatures ranging from 39.9 to 138.2°F. during the compost period. The pine-needle-cottonseed meal compost had slightly higher temperatures than the pine-needle-manure combination. Pine needles alone varied in temperature from 90.1 to 92.1°F. which was only about 7 to 10 degrees higher than the air temperature. Very little decomposition occurred, as might be expected. Urea and calcium cyanamid additions resulted in temperatures that were intermediate between the check and the cottonseed meal and manure treated composts. This indicates a probable similarity in the microbiological populations of the composts receiving nitrogen, and leads to the supposition that the greatest benefit from the manure is in this respect rather than as an inoculant.

A commercial compost accelerator, claimed to be a bacterial concentrate, was evaluated by Eno (10). Sawdust was composted, according to the accelerator manufacturer's recommendations, with soil, and soil plus nitrogen, phosphorus and calcium. There was no significant variation in the temperature among the inoculated and uninoculated piles, although the temperature of the inoculated piles was slightly higher than the uninoculated during the first few days. After eleven months of composting, the sawdust from all piles was still recognizable. Nitrate production and carbon dioxide evolution from the eleven-months old composts were quite similar regardless of treatment. Millet, grown in pots containing equal parts by volume of soil and compost from the various piles, was deficient in nitrogen but showed no noticeable difference in growth that could be attributed to the commercial accelerator. From this work and other reports reviewed by Eno (10), it appears that one can depend upon the materials composted, or the addition of soil or manure, to provide the necessary organisms in a compost pile.

Smith and Thornton (38) studied the production of artificial manures. Composts were made from water hyacinth, pine needles, Spanish moss and Spanish moss gin waste. Several different sources of nitrogen and phosphorus were used. Composts made from water hyacinth were fairly well decomposed after 4 months. Analysis showed a fair grade of manure could be made from water hyacinth and that decomposition was fairly rapid even without the addition of minerals. However, addition of minerals produced a better grade of compost. Nitrification tests showed that the nitrogen contained in the compost made from water hyacinth was readily available. Composts made from pine needles were not sufficiently de-

composed after 6 months to prevent the mobilization of nitrogen in the soil; even after 12 months the composted pine needles were not well humified. Spanish moss and moss gin waste were not well decomposed after nearly 3 months. The authors also describe how to prepare a compost pile adequate for the home gardener.

ORGANIC MATTER DECOMPOSITION

Dyal *et al.* (6) studied the decomposition of green crotalaria and green natal grass in soils varying in acidity from pH 3.71 to 7.05. All materials decomposed more rapidly and more completely in soils at pH 5.94 to 7.05 than at pH 3.71 to 4.59. The detrimental effect of acidity on decomposition was more pronounced in soils treated with natal grass than in those containing crotalaria. At the beginning of the experiment, the pH increased in the soils containing crotalaria; this was probably due to either a liberation of ammonia or the dilution effect of carbonic acid, or both. The addition of nitrogen, as potassium nitrate, to the soils containing natal grass in an amount sufficient to make them equivalent to the crotalaria-treated soils, did not increase the decomposition rate of natal grass. Nitrification was slowed in soils at pH 3.71, 4.26 and 4.59; this was probably due to the acidity and a deficiency in available calcium. They also stated that the plant materials which contained the larger percentages of hemicellulose, cellulose and lignin decomposed slower than those containing smaller amounts.

Smith and Whitehead (39) studied the effect of various amounts and kinds of cations on organic matter decomposition. Considerable decomposition by mixed cultures of organisms occurred in hydrogen saturated Tama silt loam. Decomposition in the hydrogen system was about 65 to 70 percent as great as that occurring in a calcium saturated soil. There appeared to be some correlation between degree of base saturation and decomposition, but the relationship was not close. In another experiment, using electrodialyzed Tama silt loam, there was no significant increase in carbon dioxide production up to 30 percent calcium saturation; considerable increase was obtained at 100 percent saturation. In the latter experiment, apparently the buffer capacity and the resultant low pH controlled decomposition in these cultures. Maximum carbon dioxide production from natal grass in bentonite clay-sand mixtures was obtained at 100 percent calcium saturation and maximum decomposition of glucose in this series was obtained at 30 percent saturation; the initial pH values were 8.93 and 5.80, respectively. Maximum decomposition of natal grass and glucose in the magnesium-clay systems was obtained at 70 and 100 percent saturation, respectively. In barium-clay systems, the maximum decomposition of both natal grass and glucose occurred at 70 percent saturation. Glucose decomposition was reduced to an insignificant amount in the 100 percent saturated barium clay; possibly this amount of barium was toxic. The respiration from the various systems was increased to a greater extent where calcium was used to raise the pH than where barium was used. Larger amounts of magnesium were required than of calcium to produce given pH changes and maximum decomposition. The amount of calcium, above a certain minimum, did not appear to increase decomposition and the pH appeared not to be a factor in decomposition above about 5.0 or below about 8.0.

Smith and Singer (37) reported on the effect of lignin on ammonifica-

tion in Lakeland fine sand. The amount of ammonia produced in soil treated with woodsugar lignin was slightly greater than that produced in soil without lignins. This difference was not considered significant, but it did show that lignin was not toxic and did not depress ammonification in the soil. Other work on the production of stable soil organic matter from wood waste lignins was done by Neller and Kelly (28). Their work showed that the organic matter content of soils can be increased with waste wood lignins and that this organic matter, by virtue of its lignin content, is quite stable. Where lime is used properly, lignin additions increase soil productivity. Some benefit may also be derived from the moisture holding properties of the calcium-ligno-sulfonate soil complex. Fertilizer phosphate losses were retarded by the neutral and neutralized wood waste lignin treatments. The use of wood waste lignins as a soil amendment may be limited by costs associated with such items as transportation and application despite the fact that they are in cheap supply.

Paper chromatography was used by Rothwell and Frederick (32) to determine the amino acids present during the decomposition of alfalfa and corn stover in soil incubated at 45, 60, 70, 80 and 95° F. A qualitative test for the acids was made on the 12th and 269th days. Some variations between R_f values of the pure amino acids and those in the treatment hydrolyzates were found. Temperature, presence of salts, paper, type of solvents and other interfering substances can cause variation. Cysteic acid and the following amino acids were present at one or more of the treatments in this study; aspartic acid, glutamic acid, serine, isoleucine, leucine, phenylalonine, tyrosine, threonine, alanine, arganine and valine. There were several unknown spots which reacted to ninhydrin; these may have been difficultly hydrolyzable peptides or other unidentified biological products. Temperature and the kind of material added to the soil influenced the composition of the humus. It is possible that changes in temperature altered the metabolic requirements of the different groups of organisms present which resulted in the utilization or synthesis of various proteinaceous compounds, thus altering the composition of the humus.

NITRIFICATION

Several studies have dealt with the nitrification status of soils in Florida. In 1952, Volk and Gammon (50), working on nutritional leaf roll of Irish potatoes, found that certain soils in the Hastings area nitrified poorly. These were newly cultivated soils, in general, and older soils that were strongly acid and light in texture. Liming the strongly acid soils increased nitrification and helped to prevent leaf roll.

Pritchett *et al.* (30) collected surface soil samples from the major soil types and cultural practices in the state and determined organic matter, total nitrogen and nitrate produced during 2 and 6 weeks of incubation. Correlation coefficients were determined among these properties after grouping the soils according to cultural practice and soil texture. The average organic matter and total nitrogen content were 2.52 and 0.06 percent, respectively. Nitrate produced in 2 and 6 weeks of incubation averaged 21 and 42 ppm., respectively. All three of these constituents increased with increases in fineness of soil texture. Nitrate production was better in the cultivated soils than in the virgin and pasture soils. In general, a highly significant relationship was found between total nitrogen and organic matter and total nitrogen and nitrate production. A sig-

nificant relationship between organic matter and nitrate production occurred only for certain of the cultural and textural groups with a higher degree of correlation at the end of 6 weeks than at the end of 2 weeks.

The nitrate production rate of soils in the Suwannee Valley was studied by Blue and Eno (2). Production was very slow in many of these soils that were quite acid. In some cases, nitrification was not greatly improved by liming. However, field applications of lime and fertilizer over a longer period of time than that which normally occurs in laboratory studies usually promotes nitrification. Dolomitic and high calcium lime were equally effective in improving nitrification. Efficient utilization of reduced nitrogen, from such materials as anhydrous ammonia and urea, by pearl-millet and oats growing on an acid Kanapaha fine sand (pH 5.0) was promoted by the use of lime according to Blue and Eno (3). Nitrification in the unlimed soil was very poor; two tons of lime per acre in the field increased the pH to 6.0 and resulted in a marked increase in the rate of nitrification.

Many sandy soils, such as Leon, Lakeland, Blanton and Orlando fine sands, in vegetable-and-citrus-producing areas have a high copper content. It has accumulated over a long period of time from fertilizer and spray residues. Eno (11) found that nitrification was satisfactory in all soils tested except one, despite the fact that they contained from 100 to 1600 pounds of copper per acre. Comparable amounts of copper (added as copper sulfate) applied to virgin soils of the same types generally resulted in a decrease in nitrate production. The addition of lime decreased the detrimental effect of copper. The difference in response to copper between virgin and cultivated soils may have been due to any of several conditions. Copper had been gradually accumulating in the cultivated soils and a large portion of the sulfate leached from the soil. Gradual accumulation may have resulted in the fixation of the copper in a less available form. The nitrifiers, over a period of years, may have become more tolerant of copper. All these conditions are in contrast to the application of all of the copper at one time to the virgin soils and the retention of all the sulfate. At what level copper may become toxic to the nitrifiers in the cultivated soils cannot be ascertained from this study. The maintenance of a pH above about 5.0 will do much to prevent the presence of sufficient copper in solution to become toxic to the nitrifiers.

Nitrate production in the surface soils of the citrus area is generally very good. Eno and Ford (17) sampled the surface 5 inches of soil from 67 locations which were predominantly Lakeland, Blanton and Eustis fine sands. Calcium carbonate equivalent to 2 tons per acre was applied to the soil used in the laboratory nitrification study. The average production of nitrate in 28 days at 28° C. was 211 ppm.; sixty-four percent of the soils produced more than 200 ppm. Ninety-three percent of the soils had an original pH higher than 5.5. These surface samples were taken from spreading decline areas, locations showing no decline, under grapefruit and orange trees and from the drip-line and row-middles. None of these variables affected nitrate production.

The influence of soil temperature on nitrate production is of considerable consequence in Florida. The effect of shading in celery rows during the growth of the winter crop was studied by Eno and Westgate (20). Production on the north (shady) side of rows average 2.46 ppm. of nitrate nitrogen per day; production on the south (sunny) side was 2.82 ppm. On one occasion the south-side soil temperature was 12° F. higher than that

on the north side. Eno (13) studied the effect of temperature on nitrate production in the field by incubating the soil in polyethylene bags. The bags were buried in the soil at a depth of 4 inches for periods of one to six weeks. Although soil temperatures at this depth were never below 40 °F., they varied sufficiently to result in considerable changes in the rate of nitrate production.

The rate of nitrification is also affected by the nitrogen source. Eno and Blue (15) in a laboratory study, compared the rate of nitrification of anhydrous ammonia, urea and ammonium sulfate in three acid sandy soils, Arredondo, Leon, and Klej fine sands. Anhydrous ammonia stimulated nitrification more than equivalent amounts of ammonium sulfate in limed and unlimed soil. The stimulating effect of urea was of the same general order as anhydrous ammonia. Anhydrous ammonia raised the pH into a more nearly optimum range for nitrification and initially provided a base for the neutralization of the nitric acid produced. This process was effective only so long as high concentrations of ammonia were present in the soil; in these soils, which nitrified at slow rates, this period of time was long enough to initiate a good rate of nitrification. The stimulating effect may also occur with field applications of anhydrous ammonia, since an adequate concentration of ammonia is retained in a relatively small volume of soil. The stimulation of nitrification by anhydrous ammonia has not been definitely shown under field conditions; this has probably been due to a failure to delineate the retention zone into a central core where ammonia was concentrated enough to be initially toxic to the nitrifiers and an optimum zone between the toxic concentration and that in untreated soil. In another study, Eno and Blue (14) investigated the nitrification rate in an acid Lakeland fine sand and a neutral Arredondo loamy fine sand. Compared to ammonium sulfate, anhydrous ammonia nitrified more rapidly in the slightly acid soil and less rapidly in the neutral soil. The application of anhydrous ammonia elevated the pH in the acid soil and thereby enhanced the activity of the nitrifiers by creating a more favorable environment. In the neutral soil, however, a combination of a high pH and free ammonia was toxic to the nitrifiers. Another series of nitrification studies by Eno *et al.* (18) showed this process to be inhibited by concentrations of ammoniacal nitrogen above about 300 ppm. The field situation is probably one where nitrification is inhibited within the retention zone but not at the periphery and, therefore, the nitrifiers gradually reduce the concentration of ammonia centripetally until all of it is utilized.

Nitrification is also affected by normal field applications of complete fertilizers according to Eno *et al.* (19). Compared to an unfertilized plot, 5-5-8 fertilizer, applied at one, two, three, four and five tons per acre, decreased the nitrifying potential of the soil at all rates. At four and five tons per acre, less than 15 ppm. nitrate nitrogen were produced compared to about 150 ppm. in the unfertilized soil. A further evaluation of this effect was made in a laboratory study. Using various combinations of N, P and K, it was shown that nitrification was drastically reduced by heavy applications of compounds containing these three elements. Generally, these nutrients inhibited nitrification in the following order: NPK>NK>N >NP>PK >K>P.

THE EFFECT OF FERTILIZERS ON SOIL MICROORGANISMS

The effect of field applications of anhydrous ammonia on the numbers of fungi and bacteria in Arredondo loamy fine sand (pH 7.1) and Lakeland

fine sand (pH 6.6) was investigated by Eno and Blue (14). Nitrogen was applied at 100 and 250 pounds per acre. The numbers of bacteria (and actinomycetes) were increased, except for a period not longer than 3 days after application on the neutral soil during which time they were decreased. A more detailed study of the retention zone showed that both numbers of fungi and bacteria were decreased on the first day; this decrease occurred in both acid and neutral soil. On the tenth day the numbers of fungi were still markedly reduced, whereas the numbers of bacteria had increased to 6 to 25 times the number in the untreated soil. The changes in the microbial population were noticeable while high concentrations of ammonia were present and were confined to a 3-inch zone centered on the injector row; this corresponds to the zone in which most of the ammonia was retained. From a total population standpoint, none of the changes noted are likely to permanently disturb the ecological balance in the soil. The drastic reduction in numbers of fungi in the soil treated with anhydrous ammonia indicated that there may be a possibility of it being used as a fungicidal agent in the soil. Since the application of anhydrous ammonia to soil by conventional applicators employing knife-type injectors results in large concentrations of ammonia in a localized area, Eno *et al.* (18) studied the effect of concentrations up to 741 ppm. of ammoniacal nitrogen. These studies were made in Arredondo fine sand. The numbers of fungi and nematodes were reduced by all levels of ammoniacal nitrogen from 136 to 741 ppm. Compared to untreated soil, only 0.6% of the nematodes and 4.9% of the fungi survived when 608 ppm. of nitrogen were present in the soil. This level of nitrogen regularly occurs in the retention zone when anhydrous ammonia is applied in the field. The largest reduction of nematodes and fungi occurred above 365 ppm. Field studies, on Red Bay fine sandy loam and Arredondo and Leon fine sands, showed a drastic reduction in all nematodes in the retention zone. Plant parasitic nematodes were greatly decreased and in many cases certain species could not be detected during the counting. Reestablishment of the nematode was greatest among the saprophytic species and was of the same character as that following fumigation with conventional nematocides. Further work on a field basis will be required to determine the economic value of the reduction of plant parasitic nematodes by anhydrous ammonia, which has been applied primarily for its nitrogen content. Gross elimination of nematodes is not necessary for successful crop production. Thus, it is evident that in addition to the primary use of anhydrous ammonia as a fertilizer, the destruction of plant parasitic nematodes in the retention zone also may be of value.

A soil microbiological study was made of a Pascal celery fertilizer experiment on Leon fine sand in the Sanford area by Eno *et al.* (19). The fertilizer program was as follows: no fertilizer and one, two, three, four and five tons of 5-5-8 per acre. Results showed that: fertilizer up to three tons per acre increased celery yields while four and five tons caused a decrease in yield; forty-seven percent, or more of the celery was affected by black heart with three tons or more of fertilizer per acre; carbon dioxide production and numbers of bacteria generally increased up to the three ton per acre rate of fertilizer, thereafter they decreased; fungi increased in numbers up to the four ton per acre rate with little difference between the four and five ton rates; and the nitrifying potential of the soil progressively decreased with increasing rates of fertilization until at the four and five ton rates less than 15 ppm. of nitrate nitrogen were produced.

MICROBIOLOGICAL ASSAY FOR NUTRIENT ELEMENTS

Edson and Smith (8) investigated the growth response of *Aspergillus niger* to copper in an effort to develop a biological method for the determination of copper in soils. When ½ gram of soil was added to 20 ml. of copper-free nutrient medium, a characteristic spore formation occurred which appeared to be in proportion to the amount of copper present in the soil. Edson (7) also used *A. niger*, and other fungi in a study of growth response to zinc. Of the molds tested, only *A. niger*, *Penicillium expansum* and *Penicillium chrysogenum* exhibited a distinct response to added zinc. *A. niger* appeared to be superior to other molds because of its black spore contrast and rapid growth. Above 0.5 ppm. of zinc in the medium prevented spore formation. Variations in spore color occurred below this concentration. Edson believed that with the use of a small amount of soil as a source of zinc, it would be feasible to set up a relatively simple biological test for available zinc in soils.

Edson *et al.* (9) did preliminary work on a method for microbiologically assaying soils for available boron. *Penicillium chrysogenum*, strain NRRL-1951-B25, appeared to be superior to *Trichoderma viride* in its response to boron. The greatest variation in growth response appeared to be from 0 to 1 ppm. of boron; this occurred within a narrow range of 50 to 72 hours. Thereafter, the growth quickly equalized. Growth response was determined by the number of colonies present in the flask and by the amount of carbon dioxide evolved. They believed the method has merit as a microbiological assay for boron in soils.

Flavin and Edson (22) biologically tested soil for available phosphorus by the spontaneous growth of soil organisms. They showed that a correlation existed between the amount of phosphorus available to the organisms and the amount of carbon dioxide evolved, or the amount of carbon produced. They suggested that this relationship might be utilized in developing a biological test for available phosphorus in soils, especially if correlated with field trials.

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Manganese in Florida Soils
A Review

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INTRODUCTION

It has been previously established that manganese, copper, zinc, and boron are essential for plant growth. Manganese-deficiency symptoms have been observed on many crops such as tomatoes, beans, shallu, and citrus. In Florida, symptoms have been noted in crops growing on the peat and muck soils, on the highly alkaline soils and on the light sands. Manganese is being applied in many areas, either as a spray or in the fertilizer, in order to obtain normal growth and color in the plants.

An attempt was made to survey completely the literature on the chemistry of manganese in Florida soils and especially to evaluate the extent of our information on the responses of crops to manganese applications. The aim is to delineate in a clearer way exactly what is established, on the basis of objective evidence, regarding the extent of manganese responses in relation to soil type. In some cases, the published information covers only

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the correction of obvious plant deficiency symptoms without reference to measurements of increases in yield or improvement in crop quality. In reviewing the literature, all references to demonstrated yield increases or to quality improvement will be separated from those dealing with the correction of symptoms since the latter are of uncertain practical importance except in the case of ornamentals. This procedure will focus attention on the paucity of available information on practical manganese responses on Florida soils other than marls and organic soils.

Wherever possible, reference will be made to the soil type on which the experiments were conducted though, unfortunately, authors have often failed to mention soil types in published reports.

BEHAVIOR OF MANGANESE IN THE SOIL

Carrigan and Rogers (31) found that there was a fairly general distribution of manganese in most of the Florida soils and plant materials examined. Fiskell (47), studying the solubility of manganese in Florida soils also found this to be true. He noted that both exchangeable and easily reducible manganese are several times less in the 6-12 inch layer than in the surface 6 inches of the mineral soils examined. Peat soils had approximately equal values. Fiskell and Winsor (53) reported that West Florida soils contained from 30 to 64 ppm exchangeable manganese and 200 to 400 ppm easily reducible manganese depending upon the soil type. Fiskell (48) also reported that soils having a high reserve of easily reducible manganese are Greenville, Red Bay, Faceville, Ruston, Fellowship and Norfolk. Those having medium reserves are Blanton, Scranton, Leon, Bladen and Everglades peat. When manganese fertilizer was used on Lakeland, Eustis, Ruskin, Everglades peaty muck and Perrine marl it resulted in an increased reserve of easily reducible manganese. He (49) also spectrographically determined the total manganese content of peat from the Lake Apopka area. He found that pasture fields had from 30 to 100 ppm and truck crops 40 to 70 ppm manganese. In general, there was little difference between pasture and cultivated fields. Other investigators (45, 69) have reported that manganese varies considerably in soils.

Peech (97) and Peech and Young (101) in their study of sandy soils observed that the average exchangeable manganese content of the top six inches was less than 3 lbs. per acre and that manganese is subject to oxidation and precipitation into non-exchangeable forms in soils having pH values higher than about 6.5. The fixation of manganese is very rapid at pH 8.0. The analysis of such a soil which had received 300 lbs. of manganese sulfate per acre for three consecutive years prior to sampling showed only 0.4 lbs. of exchangeable manganese per acre. Other investigators (75, 84, 91) have reported the effect of soil reaction on manganese availability. Peech (96) reported that marl soils usually had less than 1 lb. of exchangeable manganese per acre, even when manganese sulfate had been applied at the rate of 10 lbs. per tree on citrus. It has been indicated (24, 58, 101) that the optimum pH range for the maintenance of exchangeable manganese in the soil is between 5.0 and 6.0.

Wander (141) investigated the retention of manganese, copper and zinc in sandy soils, planted to citrus, over a 15 year period. During this time they were fertilized and sprayed with manganese, copper and zinc. He reported that where the soil reaction was controlled between 5.5 to 6.0, 69.5 per cent of the manganese applied was retained in the 0-6 inch layer. Where the pH was allowed to drop to 4.2 to 4.5, 1.7 per cent of the man-

ganese was retained in the 0-6 inch layer. It was suggested that the application of manganese could be greatly reduced on old bearing groves providing manganese had been applied for a number of years and if the soil reaction had been controlled. However, it is necessary to use manganese in the fertilizers for starting and growing a young grove.

Peech (98) found that the exchangeable manganese content of the soil was decreased by the application of magnesium sulfate, dolomite, and calcic lime to Norfolk fine sand. This has been observed by other workers using soils such as Red Bay, Tifton, Carnegie, Ruston, Orangeburg fine sandy loams and organic soils. Hutton and Robertson (74) working with a Red Bay soil reported that annual applications of 12½ lbs. $MnCl_2 . 4H_2O$ per acre increased the manganese content of the corn ear leaf by approximately 57 per cent. They also noticed that liming these soils reduced the amount of manganese taken up by the plant. However, Fiskell (50) noted that the addition or omission of manganese did not materially alter the manganese intake by oats grown on a Red Bay fine sandy loam. These soils had 300 to 1500 ppm when limed.

Colehour (32) reported that water-soluble manganese is quickly changed to easily reducible forms when placed on Norfolk sand. He also noted that copper sulfate and dolomite at a rate of 11 lbs. and 2,000 lbs. per acre, respectively, did not appreciably affect the recovery of manganese in the exchangeable form three months after the experiment was established. Leaching of manganese appears not to become serious until the pH drops to about 4.5 (101).

Wander (140) studied the effect of calcium phosphate accumulation in Lakeland fine sand on the retention of manganese. He reported that calcium phosphate accumulates in large amounts when the pH is maintained between 5.5 to 6.0 and that calcium phosphate is a factor in the retention of manganese in this type soil. However, it does not appreciably affect the retention of potassium when added as chlorides or sulfates. On the other hand, data obtained by Reuther *et al.* (107, 108) show that high proportions of manganese applied to citrus soil were retained in the top soil, irrespective of the phosphate treatment.

Comparatively little movement of manganese in organic soils has been observed. A relatively large proportion is held in the top few inches (40). This was found to be true under field conditions as well as in lysimeters. In analysing soil samples taken at the 0-1, 1-3, and 3-6 inch levels, following a surface application of manganese, Ensminger and Allison (43) found that there is a decreasing accumulation of manganese from the surface downward. Neller *et al.* (93) showed that a celery crop may remove more manganese than is lost by leaching.

The burning of organic soils may lead to alkaline conditions which will interfere with manganese availability. Allison and his co-workers observed that highly alkaline burned organic soil with continued cultivation, fertilization, and adequate drainage will gradually return to a normal pH range and that a more nearly normal plant growth may then result even without the use of manganese.

Soil sterilization and fumigation may affect the availability of manganese in soils. It has been noted (14) that bean leaves, grown on Everglades Experiment station plots, showed a deficiency of manganese when the soil was treated with chloropicrin and that soil sterilization and reduction in pH increased the availability of added manganese as well as of residual manganese in the soil (12, 13).

Forsee *et al.* (58) noted that manganese soil tests indicated conclusively that the values for exchangeable manganese correlated very closely with the growth response and tissue tests of shallu. The location and soil type are important factors affecting the availability of nutrient elements. This was found to be true by Janes (79) who reported that vegetables grown on Manatee fine sandy loam at Bradenton, Florida, always were lower in manganese while those grown on Marlboro fine sandy loam at Quincy, Florida were higher. Rothwell (110), Fiskell (47) and Drosdoff (41) have also reported the importance of location and soil type on availability of manganese.

In an extraction study of fertilizer-source materials, Colehour (32) noted that manganese was found to be soluble in increasing amounts with the following solutions: neutral ammonium acetate, water, ammonium acetate-hydroquinone, and concentrated acid. Working with soils, Sherman *et al.* (121) reported that the order of increasing solvent power was water, neutral ammonium acetate and ammonium acetate-hydroquinone. Camp *et al.* (24) also reported that Morgan's solution, sodium acetate-acetic acid buffered at pH 4.8, removed greater quantities of manganese than normal ammonium acetate (pH 7.0). Other workers (102) have reported procedures for the determination of manganese.

A correlation has been observed between the concentrations of manganese and iron in the following soil series: Lakewood, Norfolk, Eustis, Orlando, Blanton, Scranton, Parkwood, and Portsmouth. When the iron content was low, the manganese content was low (109).

In an experiment with tomatoes involving five levels of manganese, Janes and Jamison (80) found that minimum concentration of manganese necessary for growth of Pan-American and Marglobe tomatoes grown in a sand culture was between 0 and 0.13 parts per million. Fiskell *et al.* (51) observed that tomato fruit from plants showing manganese deficiency contained less than 0.4 ppm manganese. The plants were grown on Perrine marl and Everglades peaty muck soils in the greenhouse. They also reported that tomatoes grown on a limed or unlimed Scranton soil did not show deficiency nor toxicity symptoms of manganese. Fiskell and Mourkides (52) noted that the manganese in the leaves and stems from manganese deficient tomato plants ranged from 4-8 ppm. Normal plants had 13 ppm or higher. They also conducted an extensive comparison of manganese sources. Fiskell and Yuan (54) experimented on minor element sources on late staked tomatoes. They reported that indiscriminate use of Maneb may be harmful to both quantity and quality of the fruit.

By growing Valencia orange seedlings in pots and nutrient solutions, Smith and Specht (127) were able to observe that copper appeared to repress the uptake of Manganese and zinc by the plant. However, manganese did not show a similar effect on zinc or copper.

PLANT GROWTH CHARACTERISTICS AS INFLUENCED BY MANGANESE

The fact that manganese is essential for plant nutrition is well established. In studies of bean grown on organic soils, it was observed that manganese appeared to be essential in controlling the balance between the synthesis and destruction of chlorophyll (138). When manganese is present chlorophyll is formed in sufficient amount to maintain the plant. In greenhouse studies with raw peat, Bryan (20) reported that manganese

seemed to be closely associated with the chlorophyll development. Reuther *et al.* (105) suggested that there was no pronounced effect of manganese treatment on the rate of photosynthesis of tung. They indicated that this may be due to the fact that severe frenching tended to produce small leaves. Therefore, it may be possible that the total leaf surface is of more importance in determining the total photosynthate produced by a tree than the efficiency of the leaf surface per unit area. Lagasse (86) noted that soil applications of manganese sulfate significantly increased copper deficiency symptoms on one year old tung trees.

It has been observed (85) that the percentage of manganese in tung leaves increased as the season advanced and that manganese was significantly higher in the basal leaves as compared with midshoot leaves. Large differences in leaf composition were found due to the nature of the soils. In this regard, Roy (111) reported that soil applications of manganese caused an increase in manganese content of the citrus leaves throughout the season. The effect became especially marked after the removal of the fruit. This increase of manganese was first apparent two weeks after the first applications. Beckenbach and Spencer (17) stated that manganese requirements were highest during the early growth stages of the tomato and diminished rapidly as the plant matured. In a greenhouse experiment, these authors (18) noted that tomato plants grown on an all nitrate-nitrogen substrate have a high manganese requirement in the seedling stage, with a decreasing requirement later. Plants grown on an all ammonium-nitrogen substrate have a low initial requirement for manganese, which increases with age well through the fruiting stage. Tomato plants grown at pH 6.7 have a much higher manganese requirement than those grown at pH 4.7. They also reported that plants grown on non-aerated solution substrates have a much higher manganese requirement than those grown on aerated substrates. Bryan (21) reported that the total amount of manganese in citrus fruit juice, being 0.00042 per cent, is low compared to some vegetables.

It was noted by Camp (23) that the accumulation of manganese in the roots of citrus was very great and out of proportion to the increase in the foliage. He also noted that as the pH increased, the amount of manganese found in the roots was smaller. The author observed that large amounts of manganese sulfate repressed the absorption of phosphorus, possibly because of the formation of insoluble manganese phosphate.

Smith and Specht (128) grew valencia orange seedlings in nutrient solutions containing copper, zinc and manganese. The tops of the plants were analyzed separately from the roots. They found that the tops had lower concentrations of all metals than the roots. The root concentration increased with increased supplies of nutrients. The manganese concentration in the roots ranged as follows: normal roots, 240 to 7,800 ppm; moderately stunted roots, 18,000 to 23,000 ppm; severely stunted 42,000 to 80,000 ppm. The manganese concentration of the tops varied from 40 to 18,000 ppm. Normal plants had 40 to 910 ppm, moderately stunted had 1350 to 8,700 ppm, and severely stunted contained 11,000 to 18,000 parts per million. They report that manganese is less toxic than copper or zinc (127).

Beckenbach and Spencer (17) noted that cobaltous and cerous ions, when applied together, entirely inhibited the development of manganese-deficiency symptoms. When supplied singly, these ions become toxic at levels that still had no effect in overcoming manganese-deficiency symp-

toms. They also noted that copper or iron, or both together, influenced the severity of manganese toxicity or deficiency. Townsend and Wedgworth (138) reported that iron and zinc are not substitutes for manganese in correcting the chlorosis of beans.

Volk and Winsor (139) found no apparent increase in manganese content in cabbage after the soil had been treated with manganese; however, there was a decided increase of manganese in English-pea plants. Several of the plots showed a manganese gain of 200 or 300 per cent. It was observed by Winsor and Volk (146) that the increase in manganese in cabbage was more than 60 per cent where it was applied as a band beneath the row. There was no increase when manganese sulfate was applied as a side dressing. Forsee *et al.* (58) found that the manganese content of shallu showing some manganese deficiency was 6.4 ppm or less while plants showing no manganese deficiency contained 8.67 ppm or higher. In studying the effect of the soil pH upon 60 day old celery plants grown on peat and muck soils, it was observed that as the pH decreased from 6.47 to 5.60, the manganese content in the stems increased. (55).

Drosdoff (41) reported that leaves from deficient tung trees had less than 40 ppm manganese and those from normal appearing trees have up to approximately 2900 ppm. He also noted that apparently tung trees are able to accumulate large amounts of manganese without showing manganese toxicity.

Hurley *et al.* (73) conducted an experiment on the effect of various soil treatments on the manganese content of cigarwrapper tobacco grown on Ruston and Orangeburg fine sandy loam. They found that nitrogen from NH_4NO_3 resulted in a greater uptake of manganese in the leaves than nitrogen from cottonseed meal. Also, a greater amount of manganese was taken up when triple superphosphate was used than when steamed boned meal was the source of phosphorus. The treatments involving low calcium and magnesium plus inorganic sources of nitrogen and phosphorus resulted in very high concentrations of manganese in the leaves. They were as high as 600 ppm in the top leaves.

MINERAL SOILS

North Central Florida

Yield and quality responses.—Janes (78) and Jamison and Nettles (77) reported that manganese treatment of lettuce resulted in a decrease in yield and many plants developed chlorotic areas on the margins of the leaves. Janes and Jamison (81) failed to find a significant effect of manganese on the yield of cabbage when grown on heavily limed Arredondo soil. These authors (80) noted that with Pan-American and Marglobe tomatoes, grown in a sand culture, the content of dry matter in the plants increased from 10.2 to 13.1 per cent and 11.5 to 13.8 per cent respectively when manganese was added to the culture. They reported no yield responses to manganese. Lagasse (87) did not obtain an increase in yield of tung nuts when trees showing manganese deficiency symptoms were treated with 2 lbs. of 65 per cent manganese sulfate per tree. Pritchett (103) found that manganese sulfate increased the yield of oats from 5 to 30 per cent when grown on several types of soil under greenhouse conditions.

Killinger *et al.* (83) reported that manganese used alone or in combi-

nation with other minor elements did not stimulate the growth of carpet grass on flatwoods soils, but Killinger *et al.* (82) did observe a response of this grass to manganese when grown on Immokalee soil. Stokes *et al.* (131) was not able to obtain a great response of Spanish peanuts when treated with 50 lbs. of manganese sulfate per acre applied singly or in combination with other minor elements.

Harris *et al.* (72) observed manganese deficiency symptoms while growing oats on Arredondo loamy fine sand with a pH of 7.2. To one-half of the area, they applied manganese at the rate of 15 and 35 lbs. of $MnSO_4$ per acre while the other half received no manganese. The area which received manganese recovered and the other area did not.

Correction of Symptoms.—Jamison and Janes (76) failed to find any definite manganese-deficiency pattern on cabbage grown on heavily limed Arredondo loamy fine sand when manganese was applied to the soil singly or in combination with the other elements.

It has been reported (35, 85) that 2 lbs. of 65 per cent manganese sulfate per tree is a satisfactory soil application for correcting severe manganese deficiency on mature tung trees grown on Arredondo loamy fine sand. In experiments with frenching on tung trees grown on Arredondo loamy fine sand, Dickey and Drosdoff (35) observed that ammonium sulfate added alone or with manganese appears to increase the manganese content in tung leaves, and that magnesium sulfate did not increase the effectiveness of the manganese sulfate treatment. Reuther and Dickey (106) believe that frenching of tung trees is not confined to any particular soil or narrow range of pH, but is correlated with the exchangeable manganese content of the soil.

Gammon and Sharpe (70) studied leaf symptoms on pecans called "mouse ear." Pecan seedlings were planted on Perrine marl, Leon, and Arredondo fine sand. All minor elements except manganese were added. Typical mouse ear symptoms developed on the Perrine marl and did not develop on the Leon and Arredondo soils. The deficiency symptoms were partially corrected by treatment with a 1 to 2 per cent manganese sulfate solution applied to the leaves.

They described the "mouse ear" symptoms as follows: The midribs are shortened, changing the tips of the leaflets from pointed to rounded. The rounded leaflet is more or less cupped and slightly wrinkled. In severe cases, the size of the leaf is drastically reduced.

They reported that the manganese content of leaves from "mouse-eared" trees is usually less than 100 ppm. Normal leaves may contain from 500 to 2000 ppm manganese.

Hall and Dennison (71) obtained lime-induced manganese deficiency symptoms of strawberries grown on Rex and Blanton fine sand. They found moderate or severe leaf chlorosis when the soil pH was 6.6 or higher and the manganese content was 16 ppm or less on a dry weight basis. If the pH range was 5.9 to 6.3, little or no chlorosis was observed and the manganese content ranged from 20 to 64 ppm. At a pH range of 5.1 to 5.3 there was no chlorosis and the manganese content ranged from 94 to 222 ppm. They concluded that slight manganese deficiency symptoms could be expected if the soil pH is 6.0 to 6.5.

Central Florida

Yield and quality responses.—Roy and Bahrt (112) noted that when manganese and magnesium were added together as a soil amendment, a

significantly greater amount of vitamin C was found in the fruit of Parson Brown oranges grown on Blanton fine sand. Roy (111) observed an increased formation of sugar, a more intense coloring of the rind and juice, a greater firmness, and an increased weight of the fruit when manganese was included in the fertilizer. Bahrt and Hughes (15) also noted that when manganese was added to the soil the intensity of the color in the rind and juice of tangerines was increased. In comparing physiological sprays of copper, zinc and manganese, Fudge and Fehmerling (67) indicated that manganese had very little effect upon fruit maturity. It also did not appear to improve the fruit quality over that obtained by using copper and iron.

Correction of symptoms.—Skinner *et al.* (124) and Camp (22) have reported responses of citrus to manganese applications on both acid and alkaline soils. Leaf symptoms of manganese deficiency are found throughout the citrus growing area. These symptoms are often masked by the symptoms of zinc deficiency which are much more pronounced. The symptoms of manganese deficiency on citrus have been described in detail by several investigators (22, 25, 26). It was noted that when trees exhibiting frenching or dieback were treated with zinc to correct these deficiencies, manganese deficiency may appear in abundance. Fudge (66) did not think that manganese was an important factor in bronzing of grapefruit. Manganese deficiency has not been found to be as common on oranges as on temples, tangerines and grapefruit.

ORGANIC SOILS

Yield and quality responses.—Allison, Bryan, and Hunter (11) were among the first investigators to report the need of applying manganese sulfate along with zinc and copper to freshly broken sawgrass peat in order to obtain maximum plant growth. They reported responses of several vegetable crops to manganese, such as, endive, turnips, cabbage, and many others. Allison (6, 8) noted that beans are very sensitive to manganese deficiency on alkaline soils and that yield response was outstanding. This has been verified by several investigators (60, 61, 62, 133, 138, 142, 143). Many workers have reported that spray applications are very effective in preventing "yellows of beans." Wedgworth (143) noted that ¼ to 1 per cent manganese sulfate solutions produced the best results. Spray treatments produced higher yields than soil applications of 50 lbs. per acre of the manganese sulfate on burned organic soils. This has also been noticed by other investigators (60, 61, 62, 135).

Townsend (133) found that cabbage untreated failed completely but gave normal growth when treated with manganese. Wolfe and Fifield (147, 148, 149) obtained higher yields of potatoes when manganese was used. One hundred pounds per acre of manganese sulfate seemed to be the best rate for this crop; additional amounts gave no further profitable increase. Forsee *et al.* (59) believed that there was apparently a difference among potato varieties in their demand for manganese. Several investigators (1, 63) have observed corn-yield responses to manganese applications. Allison (2) noted a "decided" response of sugar cane to manganese, while Neller and Robertson (94) reported that little or no benefits were derived from the application of this element in experiments at Canal Point.

Forsee and Neller (62, 64) did not obtain responses of ramie to soil applications of manganese sulfate. Forsee *et al.* (58) reported that when the soil pH was lowered to 5.8 or below shallu gave tremendous growth response. This was apparently due to increased manganese availability. The leaf tissues of plants grown at the lower pH levels were found to contain a higher amount of manganese than those grown at a high pH level. Neller *et al.* (95) also observed that there is a connection between the soil pH and manganese availability. Working with peanuts growing in a well-decomposed plot, Forsee and Neller (65) and Allison (4) obtained little response to soil applications of manganese. Beckenbach (16) obtained a decided yield response of celery to applications of manganese. He recommended that one hundred pounds of manganese sulfate per acre be applied with the fertilizer the first year and twenty five pounds per acre in each of the following years. In Sanford, manganese gave no increase in yield of celery when applied alone (104). In greenhouse studies, Bryan (20) found that cowpeas grown in raw peat showed a significant response to manganese rubbed on the leaves or applied to the soil. Forsee and Neller (61) noted that manganese sprays induced normal green leaf color in bean plants and tremendously increased their yield when grown on manganese-deficient soils under greenhouse conditions.

Several investigators (17, 117, 118, 149) reported increased yields of tomatoes when manganese was used in the fertilizer. Citrus trees grown on marginal peat areas have shown no apparent significant response to manganese applications (61, 83, 92).

Correction of Symptoms.—Townsend and Wedgworth (138) noted that manganese carbonate failed to correct the chlorosis of beans, presumably because of its relative insolubility. Townsend (134, 137) and Townsend and Ruehle (136), described manganese-deficiency symptoms of beans and noted that they are not seen until the plants are two or three weeks old. He recommended an application of 50 lbs. of manganese sulfate per acre in the row to give optimum results. Forsee (57) reported observing manganese deficiency symptoms in plants grown on organic soils when the exchangeable manganese fell below 1.5 to 2.0 ppm. Plants that had an adequate supply of available manganese varied from 12 to 25 ppm manganese on an oven dry basis.

CALCAREOUS SOILS

Yield and quality responses.—According to Ruprecht (119) applications of manganese salts resulted in an increased yield when applied to crops grown on marl soils; whereas, in many cases, crops without manganese failed. Allison (4) reported that peanuts gave negative results on alkaline soils while beans and celery gave a positive response, and that tomatoes responded to residual manganese in the soil. It has been reported that the low yields or crop failures of tomatoes on marl soils may be attributed in many cases to a lack of manganese in the mineral fertilizers used (125). Skinner (122) noted that when manganese sulfate was added to the fertilizer there was always a large increase in the yield of tomatoes grown on calcareous soils. However, too much manganese may cause a reduction in yield of tomatoes grown on marl soils (90). Skinner and Bahrt (123) stated that oranges, grown on soils of pH 7.4 and treated with manganese sulfate, produced fruit that were larger, heavier, and required more pres-

sure for crushing after shipment than oranges grown on similar soils with no treatment. Camp and Reuther (29) noted a very definite increase in both acids and solids in oranges when manganese was used in the Vero Beach area.

Camp and Wolfe (30) reported increased yields of mangos when treated with manganese, while Ruehle (113) found no evidence that manganese appreciably effected the yield of Haden mangos when grown on marl soil. Lynch (89) noted that the yield of avocados for five seasons indicated an increase when manganese was added to the 66 per cent organic-nitrogen fertilizer used on several varieties. Ruehle (114) observed no improvement when manganese sulfate combined with lime was used on avocado trees affected with mottle leaf, little leaf, and rosette. There was no apparent correlation with manganese and the other elements between good and dropped fruit on avocados. Ruehle (116) found that manganese applied as a spray is beneficial to young avocado trees grown on limestone soils.

Fifield and Wolfe (46) recommended that in growing potatoes on "new marl land," manganese sulfate should be applied annually for at least the first four or five years, after which manganese could be omitted for at least one year without decreasing the yield. Malcolm (90) reporting on the manganese requirements of potatoes grown on marl soils, stated that if the marl soil had received manganese for 15 years or more, further additions may be omitted for at least 4 years. He also stated continued use of large amounts of manganese will cause toxicity. He found a reduction in yield from applications of 75 lbs. MnO per acre.

Correction of Symptoms.—Camp and Reuther (27, 28) and Camp (22) noted that manganese deficiency symptoms may be associated with and resemble zinc deficiency. Manganese deficiency has not been found to be as common on oranges as on Temples, tangerines, and grapefruit. The latter author (22) also gave a description of manganese-deficiency symptoms on citrus. It is reported (28) that spraying with manganese sulfate, combined with lime-sulfur, gave a more lasting correction than soil applications to marl soils. A disadvantage of manganese sulfate in a water solution is that it is usually washed off the leaves before being absorbed by the plant.

Dickey and Wilmot (39, 40) and Dickey (34) have reported responses of many ornamentals to manganese. "Curley bud," or "frizzle leaf" of the plumy coconut palm, *Arecastrum romanzoffianum Becc.*, may be controlled by soil application or spraying with manganese sulfate. Chlorosis of the butter-fly bush and *Viburnum odoratissimum* Ker, grown on calcareous soils was corrected by foliage applications of one per cent C. P. manganese sulfate (39).

Chlorosis of *Plumbago capensis*, downy jasmine, *Jasminum pubescens*, wax privet, *Ligustrum japonicum*, and glossy privet, *Ligustrum lucidum* and camphor tree have been corrected by foliage applications of one per cent solutions of C. P. manganese sulfate (37). Ruehle (115) noted that mottling of the leaves of *Macrocatalpa longissimo* Britt, growing on marl soil, was corrected by a single spray application of manganese sulfate and lime. Chlorosis of *Ficus rubiginosa* (38) and crape myrtle, *Layerstroemia indica* L. (36, 145) have been identified as manganese deficiencies. In addition to the above experimental results, several workers (9, 10, 19, 33, 42, 56, 144) have presented reviews on minor elements in general.

There have been many manganese investigations to date and more

should be conducted before the status of this element will be ascertained completely for Florida conditions.

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Soil Acidity and Liming

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A new era in soil science in Florida apparently began about 1936-37 with rejuvenation of the soil survey[2] which had been inactive since 1927; and the beginning of intensive detailed investigation of soil pH by M. Peech, who joined the Citrus Experiment Station staff in 1936. The early work on pH by Peech was reported in the 1937 Annual Report of the Florida Agricultural Experiment Station (11). It continued in the 1938 report, in which the first phase of a survey of pH and other characteristics of soils under citrus culture was outlined. This work culminated in the publication of the bulletin, Chemical Studies on Soils from Florida Citrus Groves (12).

Publication of a bulletin, The Soils of Florida, by J. R. Henderson (10) in 1939 gave added incentive to a systematic examination of characteristics of Florida soils. The fact that the bulletin by Peech is regularly used as a reference to characteristics of soils in the area of production of our most valuable crop, and that the generalized soil map developed by Henderson still constitutes the best statewide estimate of Florida's soil wealth wherever county surveys have not as yet been made, indicates the foresight of the men responsible for the work.

As a consequence, the groundwork for rapid progress in studies on pH and liming had been laid by the time of arrival of the writer in Florida in October of 1939. While much valuable information had been obtained on soil acidity and liming in Florida prior to this time, the work to be reviewed will be based on first hand experience and personal acquaintance with the workers in soils for the period beginning with 1939. It will be limited in reference to contributions introducing new ideas or concepts of soil pH and liming of Florida soils as they appeared in the sequence of events.

pH AND FLORIDA SOILS

The sandy soils of Florida generally are low in base exchange capacity. The value of lime in making this limited exchange capacity more effective in holding nutrient bases was a major contribution of the work of

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[2]Modern soil surveys were initiated in Alachua County in late 1936 and in Collier County in late 1937.

Peech. He pointed out that hydrogen is more difficult to replace in the soil than is calcium, by a nutrient base such as potassium when the latter is applied as a neutral salt. Prior to the work of Peech, liming of citrus was questioned as presenting a distinct hazard. The apparent reason was a carryover from a period in which attempts to lime the subsoil by excessive surface applications had resulted in poor crop production. This was done during the period of transition from the use of copius quantities of organics to the use of trace elements, and probably was a reflection of interference with availability of a very limited supply of certain trace elements in the soil.

The new liming program immediately became popular when it was shown that liming to a pH of 5.5 to 6.0 was more beneficial than allowing the soil to remain in a more acid state. The recognition of magnesium deficiency (3) gave added impetus to liming, because this element could be partially supplied by using dolomite lime to maintain the proper pH. Present recommendations generally recognize a slightly higher pH range than the original 5.5-6.0 as the most efficient for citrus production but opinions of experienced personnel vary, and refinement to an exact range by known methods of research is difficult.

Peech also showed that the apparent base exchange capacity of the sandy soils used for citrus was about 25 percent saturated with bases at pH 5.0 and about 75 percent saturated at pH 6.0. He suggested that a generalized curve of the type resulting from titration of a weak acid with a strong base fitted the data. However, a straight line from pH 4.5 at zero saturation to 6.5 at 100 percent saturation is in good agreement if the points above 7.4 where free calcium carbonate probably exists are ignored.

pH itself is logarithmic, but in soil analysis it is used as an indicator of percent base saturation. If the relation of pH to percent base saturation is linear, then it lends itself to averaging values in an arithmetic manner. The only limitation is that the soils be similar in total exchange capacity and as to the source of this capacity. It was on the basis of this straight line relationship that the writer recognized the validity of averaging pH values and began using this procedure for summarizing and analysing data on Florida soils in the early 1940's.

Early work on the method of determination of soil pH by Peech (11, 12), Carrigan (4) and Volk and Bell (18) indicated that the initial soil moisture, the soil to water ratio, and the degree of agitation of the suspension during reading with a glass electrode all had some effect on the final pH value obtained. The effect of any one factor was relatively small, therefore errors were arbitrarily limited to those introduced by the use of one volume of freshly air-dried soil to two volumes of water. The use of plastic mixes is impractical for sandy soils.

A major problem with sandy soils of low buffer capacity is the marked variation in pH readings that can result from factors which ordinarily would not be important with soils high in buffer capacity. It is for this reason that the presently recommended method for pH determination originally proposed by Carrigan includes the use of standard soil of very low buffer capacity for routine checking of equipment. It is possible to have a modern portable glass electrode pH meter that will satisfactorily adjust to two buffers of high buffer strength, yet give erroneous readings with lightly buffered sandy soils if slight leakage or stray currents exist in the system.

The effect of soluble salts on the apparent pH of Florida soils became

well known about 1942 in Florida. This has been discussed by the writer (20). Neutral salts such as the chlorides or sulfates of potassium and magnesium usually markedly depress the observed pH of a soil. Prior to about 1954 the depression was attributed entirely to equilibrium replacement of hydrogen from the soil colloids, but it is now generally accepted that replaceable aluminum on the exchange complex or aluminum soluble in various salt solutions may also be involved (9). There is evidence that both processes are functioning, but the dominant effect under the majority of conditions probably is replacement of hydrogen (26). The contribution of aluminum appears to be the result of a reaction in which the aluminum is first replaced from the base exchange by another base originating as a neutral salt, followed by hydrolysis of the aluminum salt to give an insoluble aluminum hydroxide and acid (7).

Little is known of the relative importance of permanent charge hydrogen and of pH dependent charge hydrogen for Florida soils, although an excellent start in this field has been made (25). According to the original concept of these charges (5), the permanent charge is represented by the base exchange capacity resulting from the crystal structure of clay minerals, while the pH dependent charge results from the ionization of SiOH groups around the edges of the crystals and perhaps for other reasons. Base exchange determined by the conventional neutral normal acetate method is intermediate, and apparently includes all of the permanent charge plus some of the pH dependent charge.

It appears that study of soil pH and base exchange phenomena are now entering a new era, in which not only must the old simplified explanations be questioned, but the place of soluble aluminum with its resultant toxicity to plants be taken into consideration. Account must also be taken of the effect of the phosphates in increasing soil acidity (16). These studies will be confused by the effect of soluble salts, the limited level of active calcium in light sandy soils as a medium for precipitation of the relatively copious quantities of phosphate sometimes used, and the peculiarities of the pH measurement which customarily is made at dilutions much higher than normally exist in field moist soil. This dilution factor is significant especiallly if sodium or potassium are involved (20).

LIMING

The history of liming in Florida leaves a poor impression because it appeared to take an abnormally long time to arrive at what now appears to be the obvious. As previously mentioned, the widespread establishment of a logical liming program for citrus began with the work of Peech. The recognition of a serious need for lime on the flatwoods soil came at about the time that Blaser (1) successfully introduced white clover, which responds strongly to proper liming of acid soils. Another major change was the use of lime on Irish potatoes in the Hastings area in 1952 (19). A fear of scab, and the increasing use of ammoniates as nitrogen sources during the last war gave rise to a combination of low soil acidity and low nitrate nitrogen available to the plant that resulted in nutritional leaf roll. Moderate liming to supply calcium and promote nitrification, and an increase of the nitrate nitrogen content of the fertilizer successfully corrected the condition.

The value of lime for field crops on certain soils is just now becoming appreciated generally. Lime had been used in a somewhat haphazard

manner, but recent work (2, 13) has shown that a systematic examination of liming for all field crops is in order. The depressing effect of strong acidity on molybdenum availability was overcome and whiptail of cauliflower corrected by liming (6). Numerous examples of liming tests on various Florida crops could be quoted. Existing information is sufficient to show that the use of lime, except possibly on citrus, is so far below actual potential requirement that it still must be considered as in its infancy in terms of efficient crop production.

The use of lime is not simply a matter of putting it on the soil in the proper quantity. This is more or less true for liming followed by tillage which mixes the lime with the soil for production of annual crops, but the problem with permanent crops such as citrus and pecans, and with untilled turf and forage crops is quite complex.

A major problem with citrus is the control of subsoil acidity which tends to become excessive especially when fertilizers high in ammonia nitrogen are used (17, 20, 24). Any nitrogen which penetrates to the subsoil in the form of ammonia is potentially acid-forming. It moves into the subsoil only in combination with an acid ion, and subsequent utilization of the ammonia in excess of use of the acid ion, or conversion of the ammonia ion to nitrate will leave a residue of strong acidity. Basic lime in the form of bicarbonate does not penetrate readily to the subsoil if the surface soil is more acid than about pH 5.8 (18, 23). It will react with the surface soil instead. Deliberate liming to provide surface soil pH values above the neutral range is not a recommended practice. The value of deep placement of lime has been demonstrated for certain field crops (14) and pecan nuseries (15).

The use of fertilizer high in nitrate nitrogen has been recommended at times, and the practice is logical within the limits of economy of this relatively high cost form of nitrogen. The use of nitrate of soda has been quite widely practiced under the impression that it will penetrate to the subsoil more readily than other materials and thereby give better control of subsoil acidity (24). However, sodium will not penetrate and correct subsoil acidity any faster than calcium or magnesium nitrates. These latter are not used as such because of their high hygroscoposity, but they do form in the surface soil when nitrate is formed by nitrification of ammonia or by the release of nitrate from other compounds. However, if there are both sodium and other bases present, the sodium will penetrate at the expense of those which have a stronger affinity for the soil exchange complex (20). Regardless of the cation, the amount that penetrates to the subsoil is dependent on the amount of mobile anion present. It should be pointed out that excessive sodium in the exchange complex is undesirable for crop production (8).

A misconception as to the value of sodium nitrate in the control of subsoil acidity arose as a result of measurements of subsoil pH following the use of nitrate of soda as compared to other nitrates. A given degree of saturation of a soil with sodium will produce a higher pH value than will the same degree of saturation with calcium, for example (20). But this does not indicate a greater degree of correction of subsoil acidity. It merely indicates that sodium hydrolyzes off the base exchange more readily and gives a higher observed pH with the glass electrode than would hydrolysis of calcium from the same degree of base saturation.

A misunderstanding of the effect of neutral soluble salts can also be very misleading (20). The addition of calcium sulfate to an acid soil can

lower the observed pH by a full unit, suggesting a far greater degree of acidity than actually exists. Calcium sulfate is added to soils in copious amounts in superphosphate. It does not leach readily from the soil because of its low specific solubility, and is a very complicating factor in the accurate assessment of soil pH. The use of calcium sulfate in the pH determination to partially offset this variable by establishing a new set of standards that can be interpreted consistently is suggested by the work of the writer (20).

A very serious limitation to the evaluation of soil pH for turf and permanent pastures is the difficulty of estimating effective pH where lime is surface applied. It is practically impossible to obtain a soil sample in which the pH value is not somewhat arbitrary because of the depth taken. The lime tends to remain on the surface of the soil where it is applied. A very shallow surface sample will reflect this condition, but is not indicative of the true environment of the roots. Deeper samples which include the surface will be diluted by the surface and the pH of the entire mass changed accordingly. Sampling by mircoprofile has limited practicability for routine control.

The need for surface liming where heavy nitrogen fertilization is practiced has been pointed out (21). Very strong soil acidity will develop in the shallow surface if materials such as urea, ammonium nitrate or ammonium sulfate are used consistently at high rates. Surface liming is the only answer at present, and probably is fairly successful if lime is added regularly in small quantities when examination of the surface inch shows a pH of about 6 or below. At depths greater than one inch an excess of free lime probably does not exist. Ammonia does not move as freely as nitrate nitrogen and tends to be held in the shallow surface until nitrified. When this takes place in the absence of adequate lime, the soil develops detrimental acidity in the shallow surface. Movement of calcium into the subsurface by leaching of any nitrate so formed does not increase subsurface acidity, but movement of ammonia as such will produce subsurface acidity as nitrification takes place.

Turf has a heavy mass of fibrous roots at and immediately below the surface of the soil, which apparently act as a very efficient block against major leaching of nitrogen, making the development of subsoil acidity under turf somewhat different in nature than that developed under citrus (17, 21, 24).

A factor which recently has been pointed out by the writer has considerable bearing on the efficiency of urea and ammoniates applied to the soil surface under various conditions. When urea was applied to the surface of well developed sods, from 20 to 30 percent of the nitrogen was lost as volatile ammonia (22). Losses from light sandy soils even in the acid condition were up to 60 percent. Under the same conditions the losses from neutral ammoniacal salts such as ammonium nitrate and ammonium sulfate were negligible.

However, the problem with calcareous soils or surface limed sods is not the same. Application of ammonium nitrate to Perrine marl resulted in greater volatile losses of ammonia than when urea was used, although the loss from the latter also was considerable. This is not new information, but its significance for surface limed pastures is very important, and presents one of the future problems which must be faced and now is being explored by the writer as a major study. When a pasture is surface limed, the surface of the soil may develop a pH approaching that of a

calcareous soil (18). This appears to be necessary in order to prevent undue development of acidity in the shallow subsurface as already discussed. The problem that presents itself is the volatile loss of ammonia when ammoniates are applied to this calcareous surface. If the losses are significant, then we are faced with a difficult problem, and relative greater credit would have to be given to nitrate nitrogen in a formula because it would not be susceptible to this type of loss.

A change in practices is not recommended at this time because the problem is still theoretical, and presented to show that even some of the simplest fundamentals of soil chemistry have been overlooked during the past 20 years in the problems of control of soil acidity.

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Effects of Twenty Years of Fertilization of Florida Soils[1]

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The complexity of effects of fertilization over a period of 20 years must be separated for proper study. Although no available data exist showing the exact changes with respect to soil type or the success and failure of crops on a specific area for this duration, certain information can be used to evaluate what this fertilization has been doing to Florida soils. This paper deals first with the relationship of the agricultural cash income to the fertilization. Secondly, the balance between acidity factors and liming is discussed and the accumulation of fertilizer elements is considered. Thirdly, the interactions at the zone of fertilization for several materials and mixtures are discussed. Finally an attempt is made to diagnose the fertilization trends and permanent changes in soil fertility.

TOTAL CASH INCOME AND FERTILIZATION

Good soil productivity in Florida has resulted from the recognition and use of sufficient and balanced fertilizer mixtures. For example nutritional disorders or deficiencies which were common before 1938 have become very rare because growers have learned that proper liming and fertilization must be a part of successful crop production. As shown in Figure 1, the total cash income from crops and livestock rose from $114,439,000 in 1938 to $688,989,000 in 1958. Both acreage and prices have changed this income. However, a most important factor has been the great increase in the use of fertilizer and lime. Whereas 315,813 tons of mixed fertilizer were used in 1938, the last three years have averaged over 1,300,000 tons. From Figure 1 the increase in the total cash income has paralleled the increase in fertilizer tonnage sold. Since the fertilizer was ordered and applied before the crop income was obtained, the amount of fertilizer bought must have produced the income effect rather than the fact that larger incomes enabled the purchaser to buy more fertilizer. The use of lime increased from 25,000 tons in 1938-1939 to 584,660 tons in the 1958-1959 fiscal year. From Figure 1 this increase showed a sharp change starting in 1949 up to 1955 where the amount used did not rise further. Direct benefit in terms of lime applied undoubtedly occurred which would be reflected in cash income over a longer period than one crop season. Most of the lime was used primarily to correct soil acidity of new land going into production or put on soils that had become too acidic from fertilization and sulfur sprays. In cases where a high level of copper had accumulated in the soil from copper sprays, lime has been used as a control measure for the last five

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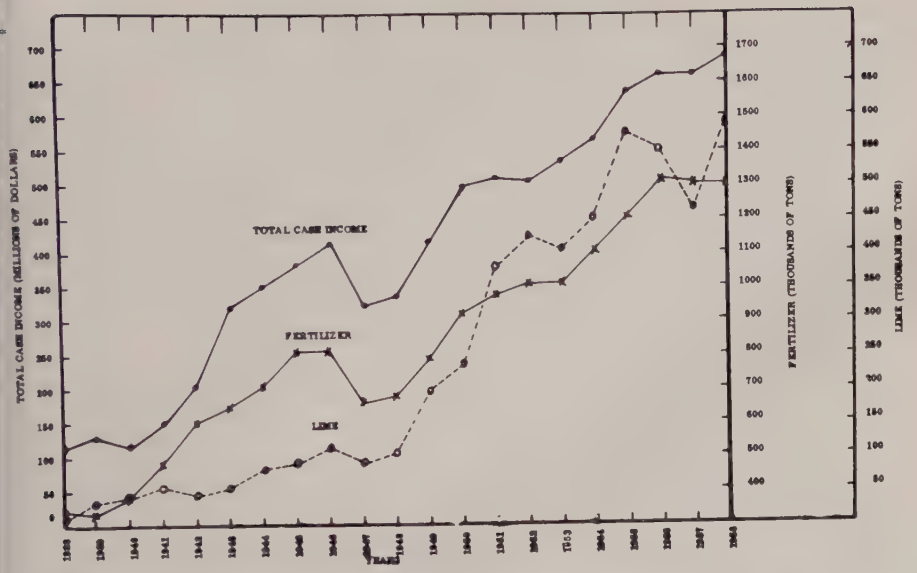

Figure 1.–Total cash income from crops and livestock (summarized by the Department of Agriculture Economics from U. S. D. A. data) is shown in millions of dollars over the period 1938 to 1958 in the top curve; tons of fertilizer used over the same period is shown in the curve with the circles and tonnage of lime applied to the soil is shown in the curve with the X- designations (fertilizer and lime data compiled from Florida State Department of Agriculture summary reports from 1938 to 1958).

years. The liming effect was to increase the efficiency with which the crop utilized the fertilizer. The use of lime is discussed further in a later section. Pritchett (25) has reported the change in use of fertilizers and sources.

In Table 1 data are given on the ratio of the cash income to the tons of fertilizer used each year. From 1938 to 1942 this ratio was about 350:1. But from 1943 to 1948 the ratio averaged close to 500:1, except in 1947 when it fell to 397:1. In 1949 cash income rose to 612 dollars per ton

TABLE 1.–RATIOS OF CASH INCOME FROM CROPS AND LIVESTOCK TO TONS OF FERTILIZER USED (\$/T) AND RATIOS OF TONS OF FERTILIZER USED TO TONS OF LIME APPLIED (T/L) FROM 1938 TO 1958 IN FLORIDA.

Year	Ratio \$/T	Ratio T/L	Year	Ratio \$/T	Ratio T/L
1938	362	12.6	1949	612	4.0
1939	359	20.0	1950	632	3.9
1940	300	10.9	1951	562	2.6
1941	308	8.7	1952	518	2.5
1942	340	13.6	1953	532	2.6
1943	500	11.7	1954	510	2.5
1944	497	8.8	1955	527	2.1
1945	473	9.1	1956	504	2.4
1946	508	7.3	1957	508	2.8
1947	396	7.3	1958	529	2.2
1948	513	6.6			

of fertilizer used and this value was 632 in 1950 and 562 in 1951. In the next 7 years the ratio averaged about 520:1. This value did not, of course, include labor and fixed costs so that net income would be a very much lower figure. Also, these values included income from land not fertilized such as came from livestock on pastures not fertilized.

Another interesting ratio change over the years was in the total tonnage of fertilizer to total tonnage of the lime used which is given in Table 1. From 1938 to 1946 this ratio was above 8.5, but in 1946 and 1947 it became 7.3. In the period of rapid increase in the use of fertilizer in 1948 to 1950 the fertilizer lime ratio fell from 6.6 to 3.9 and from 1951 through 1958 the ratio varied between 2.8 and 2.1. This use of lime did not include the dolomite used as filler in some of the mixed fertilizer.

FERTILIZER ACIDITY, LEACHING AND ACCUMULATIONS

1. *Acidity Added and Lime Balance*

Nitrification. The acidity introduced by the nitrification of ammonium nitrogen sources (NH_4 N) or organic nitrogen sources has been studied usually in the composite soil pH of the top six inches of the soil. In the complete nitrification process, one pound of hydrogen ion (H^+) resulted from each seven pounds of nitrogen in these sources (22). Most of the nitrogen used for the mixed fertilizers came from ammoniated superphosphate over the past 21 years. Although several ammoniating solutions have been used to treat the superphosphate, this product has resulted in about a 5.3 percent NH_4—N base. The average fertilizer grade over the 20 year period was 5.1 percent N, 6.99 percent P_2O_5 and 7.8 percent K_2O. In the 896,167 tons of N added to Florida soils from mixed fertilizer, it was calculated from the tonnage of P_2O_5 added that 346,000 tons of the total 896,197 tons of N sold over these 20 years was in the ammoniacal form. This was a conservative estimate of the NH_4—N added to Florida soils since it did not include top dressings with ammonium nitrate or nitrogen solutions. The potential amount of acidity (as H^+) that resulted was 49,000 tons of H^+. Using the accepted figure that one pound of H^+ would be neutralized by 50 pounds of calcium carbonate, this above acidity tonnage could be neutralized by 2,450,000 tons of lime as shown in Table 2. Estimates of potential fertilizer acidity previously made (22) failed to consider acidity loss within the soil profile or the acidity of phosphate. Nitrate movement down the profile might also result in acidity by removal of cations such as Ca, Mg, K or Na from the exchange complex and subsequent replacement there by soil acidity as H or Al on the exchange complex.

Phosphates. Acidity also was added from the application of superphosphate, or, ammoniated superphosphate (2) in addition to the NH_4^+ effect which introduced still another source. From titration of these materials to pH 7.0, each 142 pounds of P_2O_5 used added 2 pounds of H^+. Reversion of the phosphate to tricalcium phosphate, iron phosphate or aluminum phosphate also resulted in the release of H^+. From Table 2 this addition of H^+ over 21 years was 19,700 tons or 985,000 tons of lime equivalent. Movement of H^+ away from the phosphate and subsequent leaching probably occurred in addition to movement of H_2PO_4-ion through some sandy soils known to leach phosphate (23).

TABLE 2.—FERTILIZER ADDED TO FLORIDA SOILS IN 21 YEARS SHOWING RELATIONSHIP OF POTENTIAL ACIDITY, LIME EQUIVALENT AND LIME ADDED

Material	Tons added in 21 years	Potential acidity, tons H+	Lime to neutralize, tons
Fertilizers	17,493,697		
N	896,167	59,000[a]	2,950,000
P_2O_5	1,223,265	19,700[b]	985,000
K_2O	1,363,042	29,000[c]	1,450,000
		total 107,700	5,385,000
Lime	4,973,000		
		Probable deficit*	412,000

[a]Calculated from reaction of nitrification of ammoniated superphosphate assumed to be 5.3 percent NH_4N and 16.2 percent P_2O_5.

[b]Calculated from the titrateable acidity of superphosphate and ammoniated superphosphate to be 2 lbs. of H+ per 142 lbs. of P_2O_5.

[c]Calculated from the assumption that the potassium is used by the crop and the chloride leaches with H+ or Ca++ removed.

*Dolomite used as filler in mixed fertilizer is not included.

Potash. In the mixed fertilizer, potash was supplied either as chloride or sulfate. Potential acidity resulted as the chloride and sulfate leached from the fertilizer because the potassium was used by the crops and this cation must then have a replacement by H^+ or by Ca^{++}, Mg^{++}, Na^+ or Al^{+++}. This replacement must come from the exchange complex or lime since other cations are already provided as salts. Maximum potential acidity developed as the leaching proceeded down the profile was two pounds of H^+ for each 94 pounds of K_2O supplied. As shown in Table 2, this potential acidity was 29,000 tons of H^+ or a lime equivalent of 1,450,000 tons. In 1940 Volk and Peech (40) considered that absorption of bases by citrus trees affected the pH of these soils. Volk (37) showed in 1955 that neutral salts produced an acid effect on subsoils below pH 5.0 and measured the titrateable acidity leached by several salt solutions including gypsum. The acidity from gypsum and from materials other than in mixed fertilizer was not included in the estimate given in Table 4. Sulfur sprays also resulted in potential acidity at the rate of two pounds H+ per 34 pounds of sulfur applied.

Lime. From Table 4 the lime applied all these years was less than the potential acidity of the fertilizer applied. Certain fertilizer companies neutralized the fertilizer with dolomite, but unfortunately these tonnages of lime are not available so that this factor was not included in the above study. As Lyon, Buckman and Brady (22) have stated, carbon dioxide in soils and rainfall produced most of the soil acidity. One important effect of fertilization over 20 years must be the amount of acidity passing through the soil profiles and the fact that the lime used was not sufficient to neutralize this acidity, particularly acid soil profiles.

TABLE 3.—FERTILIZER, MATERIALS AND MIXED FERTILIZER ADDED TO FLORIDA SOILS IN 1958-59 SHOWING THE PROBABLE MAXIMUM POTENTIAL ACIDITY ADDED TO THE SOIL AND THE LIME NECESSARY TO NEUTRALIZE SUCH ACIDITY

Material	Fertilization added to Florida soils, tons	Potential-acidity, tons H+		Lime to Neutralize, tons
Liming total				
Calcitic	584,660			
Dolomitic	321,757			
Fertilizer materials				
Nitrogen materials	125,086	from NH_4 - N[a]	1,600	80,000
Phosphate materials	31,960	from NO_3 - N[b]	330	16,500
		from phosphate[c]	60	3,000
Potash materials	21,859	from acidic sources[d]	40	2,000
Mixed Fertilizers	1,296,611			
N	78,385	from NH_4 - N[a]	8,430	421,500
P_2O_5	83,787	from superphosphate[a]	1,180	59,000
K_2O	116,181	mostly muriate[d]	2,060	103,000
		Total	13,700	685,000
		Lime used		584,660
		Probable lime deficit*		100,340

[a]Assuming complete nitrification of ammonium and organic - N forms.
[b]Calculated as replacement H^+ or equivalent Ca^{++} if nitrate leaches out of the zone of application.
[c]Calculated from acidity of ordinary superphosphate and ammoniated superphosphate titrated to pH 7.
[d]Derived from the chloride or sulfate leaching with replacement of K^+ by H^+ or equivalent Ca^{++}.
*Dolomite used as filler in mixed fertilizer is not included.

2. *Acidity balance in the fiscal year 1958-1959*

A more detailed balance of potential acidity of materials and mixed fertilizer for 1958 is shown in Table 3. The acidity from the different materials was calculated as indicated in the above. The possibility of nitrate leaching and produced acidity was estimated from the assumption that 18 percent of the 26,237 tons of N applied as materials leached as nitrate. Despite the use of nearly 700,000 tons of lime, unless dolomite was used as filler in the mixed fertilizer, there was a lime deficit of 100,000 tons from the potential acidity of the fertilization. Obviously there were many factors that operated to retard development of this potential acidity such as direct NH_4 - N uptake by plants and the leaching of potash, but the magnitude of the acidity was such that over any extended period the effect must be particularly unfavorable for subsoil fertility.

TABLE 4.—EFFECTS OF FERTILIZER MATERIALS OR MIXTURES ON NORFOLK FINE SANDY LOAM LIMED TO pH 6.3, SHOWING pH OF MATERIAL AND RESULTANT pH, ALUMINUM AND IRON IN SOLUTION.

Fertilizer Material	Wt. per 100 ml. of H_2O	pH effect				Sol. Al in Soil-Fert. Mix		Sol. Fe 2 wks.	Total Acidity	OH From F—Action
		Fert.	Soil[a]-Fert. Mix 1 hr.	1½ da.	2 wks.	1 hr.	2 wks.			
	gm.					ppm. on soil basis		ppm.	me. per 100 gm.	me. per 100 gm.
Sul-Po-Mag	1	4.70	5.20	5.85	6.85	1.6	2.0	0.5	0.3	0.3
	10	4.10	4.70	5.15	6.45	2.0	4.5	0.3	0.3	1.3
Sulfate of potash	1	5.80	5.45	5.65	6.35	1.6	2.7	0.6	0.6	0.3
	10	6.20	0.05	5.35	5.75	2.6	3.8	1.0	0.6	0.4
Muriate of potash	1	5.75	5.20	5.53	5.80	1.8	1.6	0.1	0.3	0.2
	10	6.25	4.95	5.05	5.05	6.0	4.3	0.2	0.6	0.3
Nitrate of soda	1	6.45	5.40	5.70	6.20	0.5	0.6	0.1	0.3	0.3
	10	8.50	6.30	5.25	5.65	4.0	2.1	0.2	0.6	0.5
Ammonium nitrate	1	5.85	5.20	5.50	5.85	0.6	0.8	0.1	0.9	0.2
	10	6.00	4.85	4.90	4.85	0.5	0.4	0.2	1.2	0.3
Super-phosphate	1	3.60	4.70	5.10	5.45	6.0	2.0	1.6	1.1	0.4
	10	3.20	3.65	3.80	3.85	13.3	5.8	32.0	11.2	8.9
Gypsum	1	5.70	5.30	5.60	5.85	1.3	1.2	24.0	0.6	0.3
	10	5.85	5.10	5.45	5.60	3.8	2.4	32.0	0.9	0.7
Mono-Ca Phosphate	1	3.20	3.75	4.30	4.55	14.5	11.6	---	6.3	5.2
	10	2.90	3.05	3.30	3.10	82.5	13.7	---	108.0	23.1
N. S. Base	1	5.10	5.10	5.45	5.70	1.8	1.3	0.6	0.9	0.5
	10	4.45	4.60	4.75	4.75	6.6	1.7	0.8	8.5	3.6
Basic slag	1	10.15	7.10	7.45	8.05	1.6	1.6	0.2	None	0.4
	10	10.85	8.85	9.50	9.80	1.6	13.0*	0.0	None	0.5
Chicago sludge	1	5.80	5.90	6.25	6.35	---	3.5*	1.2	0.3	0.4
	10	5.40	5.60	5.85	6.25	1.8	1.6*	0.9	0.6	0.6
Peruvian guano	1	6.90	6.35	7.10	7.65	1.0	2.5*	0.0	None	2.0
	10	6.65	6.60	6.85	8.25	---	9.0*	0.4	None	44.3
0-14-10	1	3.85	4.95	5.35	6.00	2.9	2.0	0.2	0.3	0.3
	10	3.35	3.95	4.20	4.25	4.0	0.7	13.6	12.6	5.2
8-0-8-4[b]	1	5.95	5.45	5.45	6.70	1.0	0.6	1.0	None	0.4
	10	5.55	5.20	6.15	7.20	3.0	4.8*	0.8	None	6.0
10-0-10-3[c]	1	6.95	5.90	6.25	6.60	0.1	0.8	0.2	None	0.4
	10	7.05	5.95	6.20	6.45	0.5	0.4	0.3	0.6	0.7
10-0-10-6[d]	1	7.00	6.00	6.40	6.75	---	8.8*	0.2	None	0.3
	10	7.25	6.05	6.30	6.70	1.8	3.8*	0.2	0.6	0.3

[a]50 grams of soil stirred in 100 ml. of the fertilizer-water solutions.

[b]Formulation is 600 lbs. of ammonium nitrate, 330 lbs. of S.P.M., 200 lbs. of muriate of potash, 34 lbs. of copper sulfate, 12 lbs. of manganous oxide and 824 lbs. of dolomite.

[c]Derived from nitrate of soda, muriate of potash, sulfate of potash with magnesia, also containing 1% MnO from $MnSO_4.H_2O$ and 0.25% CuO from $SuSO_4.5H_2O$ and having phosphatic sand filler.

[d]Derived from ammonium nitrate, muriate of potash, sulfate of potash with magnesia and dolomite.

*Indicates organic matter in filtrate and this was decomposed by acid digestion to permit Al determination.

3. *Accumulations in the soil.*

The salt effect of high fertilization has been studied by Geraldson (16) who found that calcium deficiency in tomatoes was not as prevalent at low soluble salt concentration or if calcium was 20 percent of the total soluble salts. Westgate (43) noted that blackheart of celery was serious when the chloride level was above 250 parts per million (ppm.) at a pH value of 5.7.

Phosphate accumulation has been studied by several Florida workers. Neller *et al.* (23) reported that phosphorus leached out of the upper 6 inches of pasture soils unless lime had been previously applied. Reuther and coworkers (27) found that yields of oranges were not affected by the phosphate levels used. The pH, exchange capacity or Ca, K, Mg levels in the surface soil were not the same after years of treatment, whereas phosphate values were more constant. Spencer (34) noted that although the phosphorus from superphosphate leached from the top 6 inches, retention was within the rooting zone with the heaviest accumulation at 12 to 18 inches. This phosphate was soluble in NH_4F and dilute HCl and probably was held as iron and aluminum forms. In another experiment Spencer (35) later found that there was a highly significant negative correlation between the phosphorus content of roots and root concentration in the surface soil. Freeze injury (36) was related to high phosphate levels applied previously to the soil. In this study using 6-0-6-6-1-½ fertilizer at 1400 lbs. per application three times a year, the pH of 4.5 was found to a depth of 4 feet in plots without lime or phosphate. With phosphate the pH ranged from 4.5 to 4.9 in the profile. Only where 4 tons of lime were applied did the pH rise to 6.0 in the surface soil, and even then the pH was 5.2-5.3 in the subsoil. No evidence of overliming was found when the essential elements were present. Westgate, Forbes, and Blue (45) found that phosphate had accumulated at the rate of 150 pounds per year in Sanford celery soils.

Minor elements and their accumulation resulting from spray and use in fertilizer has received considerable attention. In 1941 Cowart and Stearns (3) pointed out the need for Zn, Cu, Mn and Mg in the fertilizer program for citrus soils. Lawless (20) concluded citrus showed less freeze injury and a faster recovery afterwards where the above minor elements had been applied. In 1943 Fudge (12) reported that 2 to 4 units of MgO in the fertilizer for citrus prevented bronzing or magnesium deficiency either for Duncan or Marsh grapefruit, and acidic or basic inorganic-N did not alter the degree of Mg-uptake. In 1946 Fudge (13) found that K-intake by citrus was much greater than Ca and Mg on unlimed soils but nearly the same as Ca and greater than Mg on limed soils. Earlier, Bahrt and Hughes (1) had shown that magnesium sulfate, dolomite or calcined kieserite corrected magnesium deficiency of orange trees. In 1943 Jamison (18) concluded that phosphate accumulation has little effect on the fixation of zinc and copper in the soil since the fixation is far stronger than was indicated by the solubility of the phosphates or basic forms of these elements. Reuther, Smith and Specht (29) published in 1951 the first comprehensive evidence that accumulations of Mn, Cu, Zn and phosphate occurred over the seven years tested in the top 9-inch depth of several citrus soils. They found that the retention of copper was from 86 to 450 pounds per acre in the top 6-inches of citrus soils more than 20 years old.

In 1952, the relationship of iron chlorosis to the high level of copper and the possible toxicity of the latter to roots was recognized by Reuther and Smith (28). Westgate (44) and Stewart and Leonard (21). In old celery fields Westgate found 10 to 60 times as much copper as in virgin soils. Also, chlorosis set in when the Cu exceeded 250 pounds per acre at pH 5.7 or 500 pounds at pH 6.7. In the soil profiles examined by Reuther *et al.* the major portion of the Cu and Mn was in the top 3 inches, whereas phosphate was ten times as high and only slowly decreased down the profile and total iron remained about the same in each depth sampled. They concluded that organic matter fixed the heavy metals and root damage would result if copper was too highly available even for a short time. Since Ford (11) reported that two-thirds of the feeder roots of citrus were in the subsoil, the leaching of elements into the subsoil must also be considered. Fiskell and Westgate (10) found that copper was not leached more at higher rates of fertilization, and a water-soluble value of 0.5 ppm. Cu was the maximum tolerated by some vegetable crops. Fiskell (7) showed that phosphate did not mobilize minor elements appreciably in Everglades peat, whereas a nickel salt or a chelating chemical removed practically all the minor elements thereby providing proof that the heavy metals were held by organic matter in a chelate-like manner.

4. *Soil acidity studies.*

In 1942 Jamison (17) pointed out the need for considering the acidity introduced to citrus soils by sulfur sprays and acid fertilizer. Even though 3 tons of dolomite was used, the carbonate did not accumulate but both exchangeable forms and leaching occurred. A pH of 5.5 to 6.0 was recommended. In 1940 Fudge and Fehmerling (14) reported that in the nitrogen source plots at the Citrus Experiment Station after Cu, Zn, Mn and Mg deficiencies were corrected, the N-P-K program was rejuvenated and that bone meal showed up better than superphosphate on the acid plots. Sites and coworkers in 1955 (31) reported that in the nitrogen source test on citrus the pH varied from 5.7 to 4.2 depending on years more than sources and recommended a pH of 5.5 to maintain nitrification effectively. Wander (41) reported some increase in subsoil pH where the N-source was $NaNO_3$. Rassmussen and Smith (26) found that a pH of 6.0 in the subsoil was best for citrus growth. At pH 4.0 growth was poorest both in pot and field studies. Gammon (15) showed that where sodium or potassium dominated the exchange complex, the root growth was very poor and calcium must be present in the rooting zone. Smith and Rassmussen (32) found that absorptive processes of roots had little effect on the pH developed with and without dolomite at the same fertilization level. However, in Orlando fine sand limed to pH 7.4, twice as much acidity formed where $(NH_4)_2SO_4$ was used as NH_4NO_3 at the same rate of N. Factors involved in pH measurement and the interpretation for Florida soils have been studied by several workers (4, 9, 17, 37, 38, 39, 40).

Wander (42) studied the effects of nitrogen sources on changes in pH resulting from root feeding and found that 80 times as much acid was produced in the all NH_4—N case as the all NO_3 N case. Also, the exchange capacity of the roots was much higher at the higher nitrate levels. With proper control by a good liming program, he concluded that favorable rapid nitrification of ammonium sources would result. In field plots, Smith and Reuther (33) noted that approximately the same pH of 4.7 occurred below 12 inches regardless of the source of N where calcium

nitrate, ammonium nitrate and ammonium sulfate were in the test. Also, when the soil was limed at five tons per acre, the pH increased only in the 0-6 and 6-12 inch depths. Robertson *et al.* (30) analyzed several soil profiles after several years of fertilization and found that both exchangeable-Ca and pH below 0-6 inches were not affected by liming the Red Bay fine sandy loam and only slightly so in Ruston fine sandy loam. However, in Norfolk loamy fine sand liming increased the pH down to 30 inches. Whereas limed soil was higher in Ca to 18 inches, the unlimed soil was higher in Ca at depths from 18 to 30 inches. In Klej fine sand at Live Oak, the effect of pH and liming was found only to be acting to a depth of 12 inches.

All of the above studies have indicated the acid nature of subsoils under fertilization, but pH could not indicate the pattern of acidity going through the profile or the amount involved. Since most Florida subsoils are natively very low in nutrients and are acid, the scrubbing action of leaching might not alter the pH as much as might be expected since the clays have a normal pH in the range of 5.1 to 5.3 primarily from aluminum saturation (8). Release of aluminum in the leaching process might be quite unfavorable for root growth and yields (9). Where copper has accumulated, the same acid situations may promote poor root growth.

The effect of fertilizer concentration bore an inverse relationship to nitrification in studies conducted by Eno and coworkers (5). The subsoil in citrus soils nitrified poorly at pH 5.4 down to 4.6, but when limed to pH 6.6 Eno and Ford (6) concluded that nitrification would proceed normally after a build-up of nitrifying organisms. Data on other soil properties and microbial counts were also given in this paper.

EFFECTS OF FERTILIZER MATERIALS ON THE SOIL AT THE FERTILIZATION ZONE

A relatively unknown phase of the fertilization effect on Florida soil has been the reaction in the soil where the fertilizer contacted the soil, herein designated as the fertilization zone. With row fertilization this zone has usually been placed within a few inches of the seedlings. Such fertilizer placement has been studied in terms of crop yield and intake of nutrients, but not from the soil standpoint. Obviously this fertilization zone has been the origin from which the fertilizer materials moved into and reacted with the soil and where crop roots fed. Leaching of fertilizer also proceeded through this zone as water moved through in excess of the water-holding capacity of the soil. To illustrate the reaction between soil and fertilizer, several representative fertilizer materials and grades were mixed with Norfolk fine sandy loam at the ratio of 1:50 and 1:5 fertilizer to soil. This soil from the West Florida Experiment Station had been limed to pH 6.3, produced corn yields approaching 100 bushels and received annually 200 pounds each of N, P_2O_5 and K_2O. This soil was chosen because the fertilization and productivity were both high in comparison with many other soils in Florida. Both clay and organic matter were present in amounts sufficient to provide buffering and exchange reactions with much of the fertilizer added.

Acidity of fertilizer materials. The pH of 1:100 and 10:100 fertilizer to distilled water mixtures was measured by the glass electrode after vigorous stirring. This pH did not change after 18 hours. Mono-calcium

phosphate, superphosphate and 0-14-10 fertilizer were the most acidic of these materials (Table 4). Sulfate of potash magnesia (Sul-Po-Mag) and nitrogen solution base (NS. base) were less acidic than the above materials but much more acidic than gypsum, muriate of potash, sulfate of potash, Chicago sludge, 8-0-8-4 fertilizer, ammonium nitrate, nitrate soda and Peruvian guano in order of decreasing acidity. The two 10-0-10 fertilizers which contained dolomite filter were nearly neutral and basic slag was very alkaline.

Initial acidity effects of fertilizer with soil. To each fertilizer solution used in the above, 50 grams of the soil was added. There was little, if any, change in the pH measured as soon as the fertilizer solution and soil were mixed and after one hour with stirring. Except for the alkaline solutions the pH was lower at all the 1:5 fertilizer to soil ratio than at the 1:50 ratio. Sulfate of potash, muriate of potash, ammonium nitrate and 8-0-8-4 fertilizer produced pH values with the soil more acidic than that of the fertilizer solution previously used. These acidities are shown in Table 4, and in column 7, the aluminum in the filtrate passing 2 filter papers (No. 3 Whatman) is shown. Note that mono-calcium phosphate and superphosphate produced the largest amount of soluble aluminum; the muriate of potash, nitrate of soda, N. S. base, 0-14-10, gypsum and 8-0-8-4 fertilizer produced more than 2 ppm. Al and the remaining materials released less Al than the above ones. The extraction of Al by other salts from other soils has been reported (9, 47).

Acidity effects after 36 hours. After 36 hours the pH of the fertilizer-soil mixtures was higher in all cases except for nitrate of soda at the 1:5 ratio. This indicated a small degree of buffering effect on the initial acidity. These values are shown in column 5 of Table 4.

Acidity effects after 2 weeks. The containers were covered for 2 weeks and the pH measurements made after vigorous stirring. One half of the agitated mixture was taken for filtration and one half for leaching studies. After two weeks the acidity of all materials at the 1:50 ratio decreased. At the 1:5 ratio the pH was generally higher except in the case of muriate of potash, superphosphate, mono-calcium phosphate, N. S. base and 0-14-10, where the pH remained about the same as measured after 36 hours. Analysis of the filtrates was made for Al, Fe, total acidity and hydroxyl release, the latter by the procedure of Yuan (46), and the data are given in columns 8, 9, 10, 11 of Table 4. The soluble Al was above 2 ppm. on the soil basis after sulfate of potash magnesia, sulfate of potash, muriate of potash 1:5, superphosphate, gypsum 1:5 and mono-calcium phosphate. Where organic matter was dispersed as was the case for basic slag, Chicago sludge, Peruvian guano, 8-0-8-4 fertilizer 1:5 and the 10-0-10-6 fertilizer, the Al was above 2 ppm measured after peroxide treatment to destroy the organic matter. Soluble Fe was highest where gypsum 1:50 and 1:5, superphosphate 1:5 and 0-14-10 at 1:5 ratio were involved. Titration of the total acidity of the filtrates showed the phosphates at the 1:5 ratio were the most acid producing, possibly because fixation or reversion reactions were exceeded at these rates. The fluoride complexing effect on Al, Fe, Mn in the filtrates released OH from these hydroxides and this titration shown in the last column reflected the amount of these minor elements released by the fertilizer materials. The significance of these studies was not only the acidity released but the soluble Al and Fe found in what

would resemble the fertilization zone. Feeder roots that encountered such acidity release might be injured and especially so in a more acid soil or with less buffering capacity. Dunton *et al.* (4) reported acidity migrated from the fertilizer band before it could be neutralized by dolomite. On soils high in accumulated copper, a very real hazard from excessive copper availability released by such acidity might be a very practical reason for preventing such acidity release by dolomite filler in the fertilizer and by a proper liming of the surface soil.

Leaching studies of fertilizer materials. One-half of the above fertilizer-soil samples was transferred to a 100 ml. centrifuge tube, stirred well and centrifuged at 2000 rpm. for 15 minutes. The pH and conductivity were measured in the supernatant solution which was poured from the soil. Then 50 ml. of distilled water was added, stirred thoroughly for one minute and the suspension centrifuged again. The pH and conductivity of the supernatant solution were measured. This process was repeated until

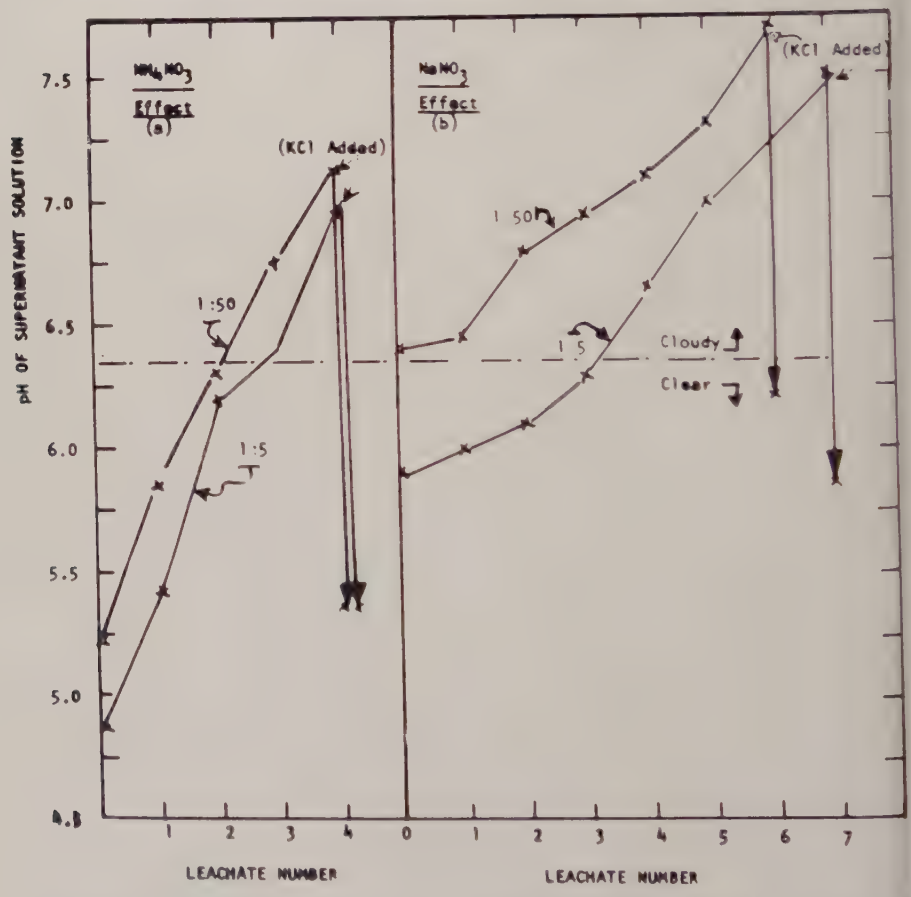

Figure 2.—Changes in the pH of successive leachates from Norfolk fine sandy loam treated with (a) NH_4NO_3 at 1:50 and 1:5 ratios to soil and (b) with $NaNO_3$ at 1:50 and 1:5 ratios. The verticle arrows indicate the fall in pH when N KCl was added to the soil after the final water leaching.

the conductivity fell to less than 0.1 millimhos cm. as measured by the Solu-Bridge Soil Tester. After the supernatant at this stage was poured off, 50 ml. of 1.0 N KCl was added, stirred as before and centrifuged. The pH of this supernatant solution was measured.

In Figure 2 the pH changes with progressive leaching are shown for ammonium nitrate and sodium nitrate. The rapid rise in pH was attributed to removal of nitrate ions leaving the exchange complex saturated with the cation. Equilibrium of the cation with the water and exchange sites produced hydrolysis of the water to form hydroxyl ions and bicarbonate ions, the latter in proportion to the dissolved carbon dioxide in the water. The dispersion of the clay was seen to be appreciable above pH 6.3 and most pronounced as the conductivity decreased and the pH rose above 7.3. Monovalent cations have been used for many years in the dispersion of clays. For the above fertilizer materials organic matter was deflocculated to some extent by the sodium nitrate after the conductivity fell below 0.5 mmhos. The drop in pH on the addition of the neutral KCl solution was accounted for by replacement of H^+ and possibly Al^{+++} from the exchange complex, with $Al(OH)_3$ precipitation and resultant H^+ release from this reaction. The pH approached the same acidity as the soil and fertilizer material gave after two weeks of standing. The above phenomenon of pH change showed the pH dependence on the fertilizer salt concentration remaining in the soil. This would be an unreliable measure of lime requirement, whereas the pH in the KCl solution indicated more closely the soil reaction or H^+ producing capacity.

In Figure 3 the effects of leaching the muriate of potash and sulfate of potash from the soil are shown. The pH rose much more rapidly for the KCl at the 1:50 ratio than at the 1:5 ratio. Also the leaching of the sulfate of potash both at the 1:50 and 1:5 ratio was slower than for the muriate, although the final pH ranges were alike. On addition of further KCl solution the fall in pH or acidity released was large, as shown in Figure 3, but not to the same pH exactly as at the start of the leaching. Explanation of the pH changes was the strong anion removal prior to the potassium. Clay dispersion occurred above pH 6.3 as before. In 1943 Kime (19) found retention of K high when muriate alone was used, but in mixed fertilizer Ca and K leached alike and faster than Mg. Fudge (13) reported Ca and Mg effect on K intake by citrus.

In Figure 4 the changes in pH as phosphate and associated salts are leached from the soil are shown. The pH rose rapidly in the first 4 leachings for both ratios of mono-calcium phosphate and superphosphate in the soil. After 4 leachings of mono-calcium phosphate the conductivity and pH became constant at the 1:50 ratio. Many more leachings were needed for the superphosphate in the same ratio and this was likely from the gypsum part of the fertilizer (2). After 14 leachings of the soil treated with mono-calcium phosphate at the 1:5 ratio, N $CaCl_2$ was added which dropped the pH from 5.25 to 4.25. After 6 more leachings with water, N KCl was added and the pH fell from 5.30 to 4.35. In the case of the superphosphate the conductivity persisted at 2.0 mmhos. even after 26 leachings with twice as much water as soil. This was caused chiefly by dissolving of gypsum from the superphosphate added. No dispersion of clay occurred. Changes in pH as sulfate and phosphate were leached likely reflected the degree of Ca^{++} equilibrium between soil and water. The drop in pH after the phosphate was at equilibrium and the N KCl was added showed the error in assuming the pH in water measured the degree

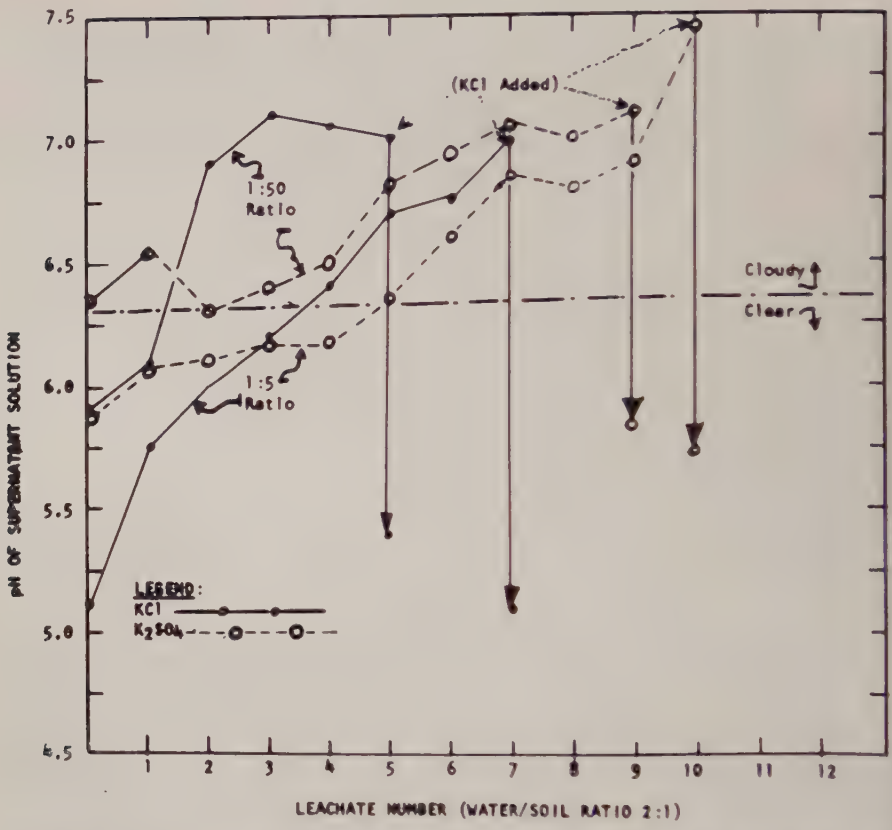

Figure 3.—The pH changes of successive leachates from Norfolk fine sandy loam that had received KCl or K_2SO_4 in either 1:50 or 1:5 ratios to the soil. Fall in pH on addition of N KCl is indicated by the vertical arrow for each treatment.

of acidity on the exchange complex. This was in contrast to the conclusions made by Peech (24) that pH 5.5 represented 50 percent saturation.

In Figure 5 the behavior of N.S. base, 0-14-10 and gypsum treatments of Norfolk fine sandy loam during successive leachings with water is shown. At the 1:50 ratio 4 leachings reduced the gypsum to a negligible salt level and the pH was constant after second leaching. Addition of N KCl at this point dropped the pH from 5.75 to 4.30. With the N.S base the pH rose to 6.55 with the leaching and dropped to 5.45 on addition of N KCl. In the case of 0-14-10 at the 1:50 ratio a final pH of 6.5 with leaching occurred and drop in pH to 5.80 occurred after addition of the N KCl. After 26 leachings of these three fertilizer materials at the 1:5 ratio, the conductivity was 2.0 mmhos. No dispersion of clay was noted. Obviously gypsum in these three materials persisted in the soil and exerted a somewhat similar effect on the successive leachates. Fluctuations occurred when the interval between leachings was more than several hours. The difference between the resultant pH at the 1:50 ratio and 1:5 ratio illustrated the effect, in this case a persistent one, on the pH or acidity release from the soil.

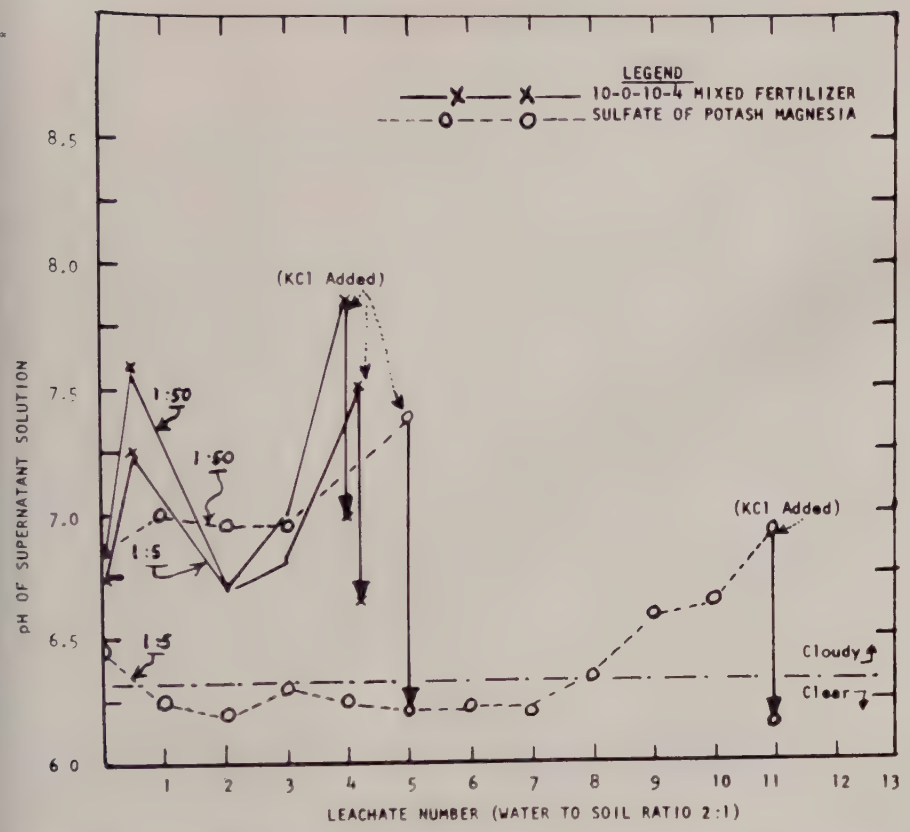

Figure 4.—The effect of monocalcium phosphate and superphosphate on the pH of water leachates from Norfolk fine sandy loam. The pH change on addition of neutral salts is indicated by vertical arrows.

In Figure 6 the pH changes in leachates of the soil receiving the 8-0-8-4 and 10-0-10-3 fertilizer are shown. Here all supernatant solutions were cloudy from dispersed clay. The pH differences between 1:50 and 1:5 ratios used were rather narrow and in the range 7.0 to 7.75. Both grades of fertilizer gave a somewhat similar pH pattern and the drop in pH for the 1:50 ratio were the same, 7.6 falling to 6.25. The pH in water as leaching progressed was influenced by the cations Na^+ and K^+ in the case of the 8-0-8 fertilizer and NH_4^+, K^+ and dolomite in the case of the 10-0-10-3 fertilizer. The drop in pH on addition of N KCl contrasted sharply with the pH found in water.

In Figure 7 the change in pH from leaching of sulfate of potash magnesia and 10-0-10-6 fertilizer containing dolomite is given. At both the 1:50 and 1:5 rates of fertilizers to soil the pH rose above 7.5 after four leachings and dropped nearly one pH unit after N KCl was added. At the 1:50 ratio of sulfate of potash magnesia, after the 5 leachings required to leach out the salts, the pH was 7.4 and fell to 6.2 on addition of N KCl. At the 1:5 ratio with this fertilizer material 11 leachings were required

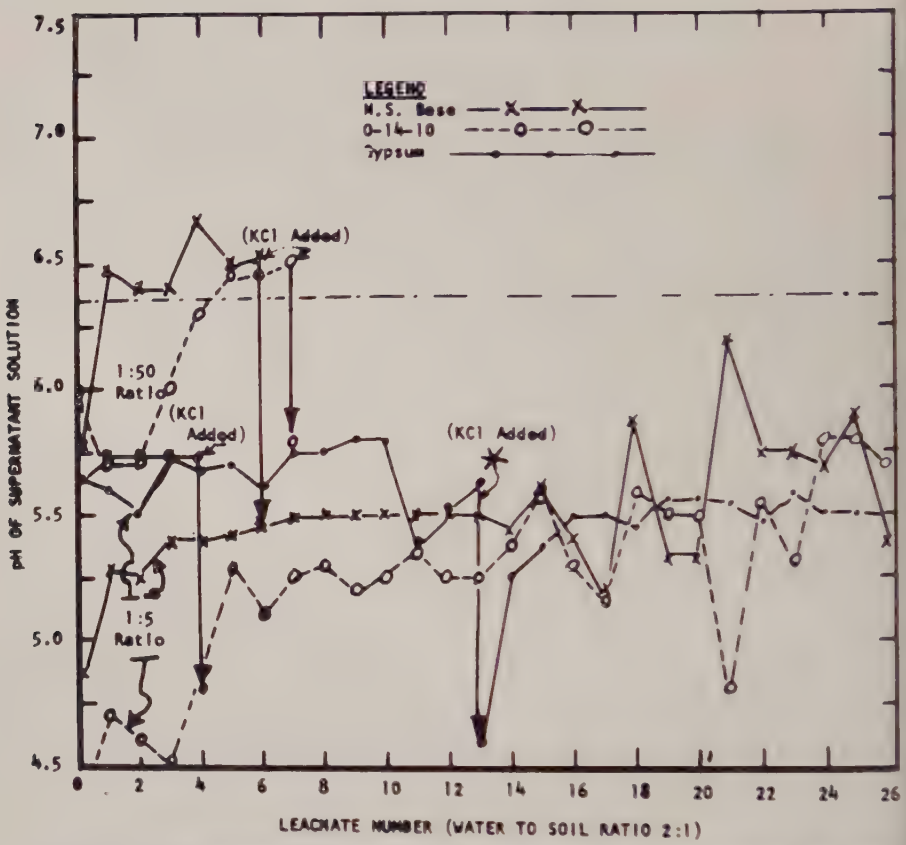

Figure 5.—The effect of N.S. base, 0-14-10 mixed fertilizer and gypsum on the pH of successive leachates from Norfolk fine sandy loam fertilized at ratios of 1:50 and 1:5 to soil. The vertical arrow indicates the drop in pH on addition of N KCl at this stage of the leaching.

resulting in pH 6.95 and a decrease to pH 6.15 on addition of N KCl. Dispersions of clay occurred above pH 6.3.

As indicated from the above experiments, as many fertilizer materials were leached out of the soil, clay dispersion took place. This might be an important soil factor over a period of years. Clay movement from the fertilization zone into soil acidic enough to flocculate the clay might result in hardpan or cultivation pan development which are unfavorable for crops because root systems become restricted under these conditions. Furthermore measurement of soil pH after fertilization was drastically different in water compared to dilute KCl, particularly so since the pH in water was dependent on the residual salt concentration of the fertilizer.

CONCLUSIONS, FERTILIZATION TRENDS AND SOIL REACTIONS

From the rather incomplete soil research data about fertilization effects and the statistics on fertilizer and lime use, certain conclusions were evident. Others must be deduced from work done in the laboratory.

1. Total cash income from crops and livestock has increased six-fold in

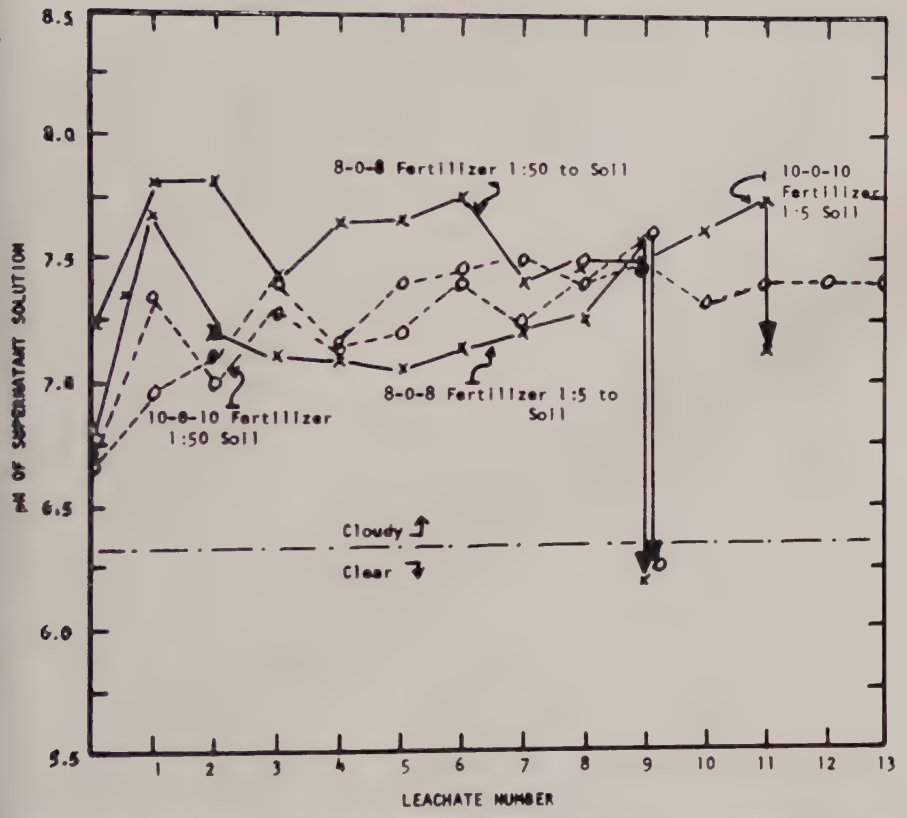

Figure 6.—Changes in pH as soil fertilized with 8-0-8 and 10-0-10 fertilized at 1:50 and 1:5 rates to soil are leached with water and finally by N KCl.

the last 20 years. This soil productivity was caused mainly by the four-fold increase in the use of fertilizer and twelve-fold increase in the use of lime since 1938.

2. Fertilizer was used in recent years at twice the tonnage of lime.

3. Potential acidity from fertilization resulted from nitrification, phosphate and the leaching of chloride, sulfate, nitrate and phosphate. Total lime use was less than the potential acidity from the total fertilizer added.

4. Soil organic matter because of its high cation exchange capacity and very low anion exchange capacity (7) held fertilizer cations stronger than sulfate, chloride, phosphate or nitrate against leaching. Accumulations of copper, zinc and manganese from fertilization and pesticides occurred and were held by chelate-like link to organic matter rather than as phosphates.

5. Role of clay in fertilization reactions received attention in recent years. Sands formerly treated as sand cultures accumulated phosphates as the aluminum and iron forms rather than as calcium phosphates. The presence of soluble aluminum derived from clays was recognized and varied with the acidity of the fertilization.

6. Lime in the topsoil containing most of the feeder roots corrected acidity, improved nitrification and prevented root injury from copper and aluminum excessive availability.

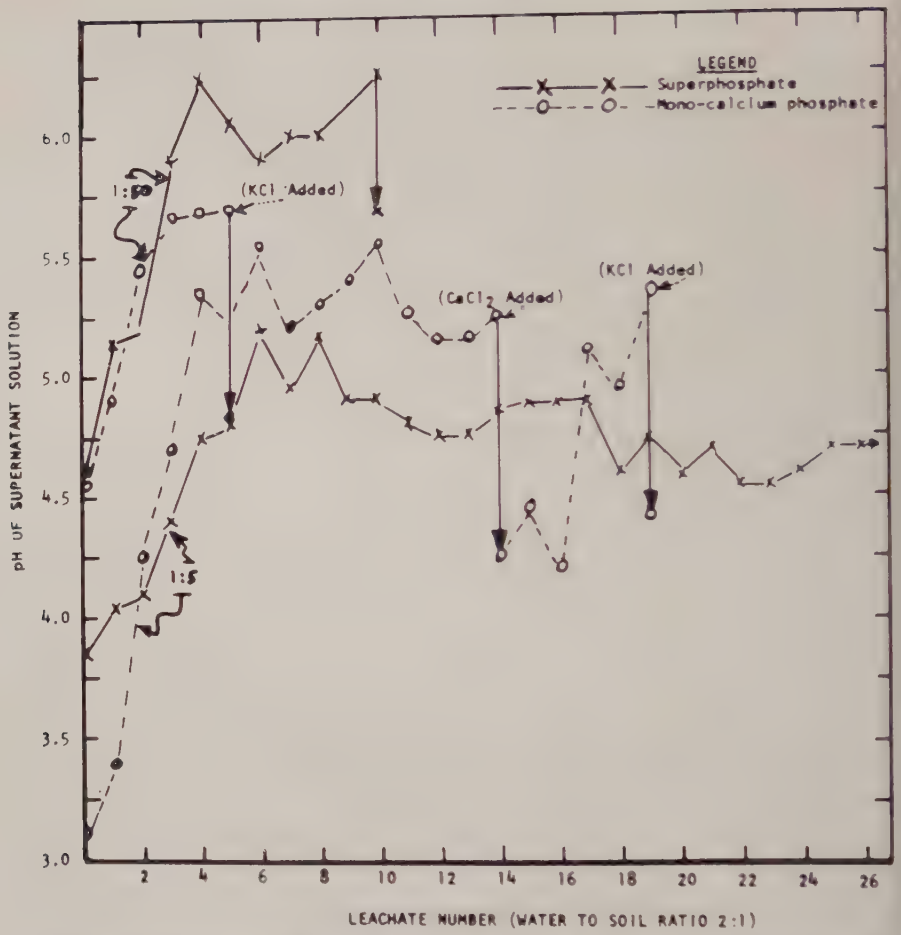

Figure 7. Changes in the pH of successive leachates from Norfolk fine sandy loam (pH 6.3) treated with 10-0-10 fertilizer and sulfate of potash magnesia at 1:50 and 1.5 ratios to the soil. Vertical arrows indicate the fall in pH when N KCl was added to the soil after the above fertilizer materials were finally leached.

7. Subsoil acidity rarely was corrected by liming the topsoil. Reaction of the lime to provide exchangeable calcium and magnesium occurred. These cations, when combined with the excess fertilizer anions leaching through the subsoil, provided a favorable nutrient situation for deep-rooted crops but subsoil acidity as measured in water might not be affected.

8. Addition of fertilizer resulted in a much more acid soil at the fertilization zone. This acidity decreased after 2 weeks except when the phosphate exceeded the fixation capacity.

9. As the soil in the fertilization zone was leached, the soil became less acid or even alkaline and in the latter case clay dispersed. Where gypsum or phosphate was used, the soil remained acid and the clay stable. This effect in the zone occupied by feeder roots would be localized by surrounding acid soil.

10. Soil acidity measured in water, before or after fertilization, in no case was similar to that measured in a neutral salt solution. Such pH in water was erroneous for estimating the lime requirement and unrealistic for proper soil management.

11. Present fertilization programs have provided a balanced soil fertility. Deficiencies have become rare. Crop yields have increased. Further refinements, particularly subsoil fertility, required more research to encourage better root systems and more efficient use of soil water.

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TWENTY YEARS OF PROGRESS IN CROP BREEDING IN FLORIDA

Small Grain Breeding in Florida During the Past Twenty Years[1]

W. H. Chapman[2]

Small grains are grown in the north-central, northern and western parts of Florida as a winter pasture and grain crop. They furnish green forage during the fall and winter months when permanent pastures are generally dormant and non-productive. Also, they provide winter cover for the land and reduce erosion from wind and water. The small grains are well adapted to modern mechanical production.

Most of the small grain acreage is planted to oats either for forage or for forage and a subsequent grain crop. There is an increase in interest in rye because of its ability to grow on light, sandy soils and with less fertility than other small grains, and because of less damage from plant diseases and more growth at lower temperatures than oats or wheat. Wheat is grown extensively in extreme west Florida, especially in rotation with soybeans. At present no variety of barley is suitable for commercial production.

OATS

Short items in agricultural journals issued prior to 1860, such as the Southern Cultivator, indicated that oats were very poorly adapted to the warm climate of the South, and that rust was a serious limiting factor in their production (18). Oats became a more certain crop with the advent of the Red Rustproof type on which crown rust (*Puccinia coronata avenae* Eriks and Henn) appears later in the development of the plant than on other susceptible varieties, and which consequently partly escapes rust damage. The term "late ruster" has been used to describe this quality of the Red Rustproof oat. Prior to 1939, selections from this type were among the highest yielding entries in the Florida nurseries. Good yield and apparent crown rust resistance would indicate that most of the commercial acreage prior to 1939 was planted with various selections and strains of Red Rustproof oats.

Prior to 1935, limited variety trials were conducted with such varieties as Texas Rustproof, Hastings 100 Bushel, Nortex, Appler, Alber, Fulghum, and Country Common. Breeding was limited to selection within the existing varieties which were quite variable.

Diseases have always been of utmost importance in oat production and breeding. In 1923 the following statement occurred in the Annual Report[3]: "The question of yield of oats, either for winter grazing, hay or grain, hinges largely on the ability of the oat to resist rust. Since disease resistance

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[1]Florida Agricultural Experiment Station Journal Series, No. 1038.

[2]Agronomist-in-Charge, North Florida Experiment Station, Quincy, Florida.

[3]This statement and others following not covered in the Literature Cited were obtained from Experiment Station Annual Reports.

is such a factor in this study of high yielding strains of oats, it is deemed best to carry all future work with oat varieties along in cooperation with the Department of Plant Pathology." During the period 1923-1939 stem rust (*Puccinia graminis avenae* Eriks. and Henn.) and Helminthosporium leaf spot were mentioned as new problems. Even though notable advances have been made in breeding disease resistant winter oats, the problem of new and virulent races of pathogens still persists.

A new era in breeding for crown rust resistance was introduced with the discovery of the Victoria resistance to crown rust (11,12,14). Victoria (12) was resistant to all collections of crown rust identified among those from the United States, Canada, and Mexico during the nine-year period 1927-1935, and also to loose smut (*Ustilago avenae* (Pers.) Rostr) and covered smut (*Ustilago kolleri* Wille.). In 1931 H. C. Murphy working at Ames, Iowa, discovered the exceptional crown rust resistance of the Australian variety, Bond. These discoveries resulted in numerous crosses between Victoria or Bond and leading agronomic varieties.

During the period 1935-1939 numerous selections were made from hybrid materials received from the United States Department of Agriculture and the Georgia Agricultural Experiment Station, involving Victoria or Bond crossed with Fulghum, Alber, and Red Rustproof varieties. The importance of crown rust was so significant that, even though Victoria was a very poor variety agronomically, one and one-half acres was planted in 1934 for increase and possible release from the North Florida Experiment Station.

The period from 1939 through 1945 was probably the most significant in oat breeding and production in Florida. In 1939, F_4 crown rust resistant selections from Victoria crosses produced significantly higher grain yields than available varieties, and certain superior selections were planted in increase blocks at the North Florida Experiment Station. The late J. D. Warner selected Quincy Red C. I.[4] 4077, also known as Quincy 1, from a cross between Kanota and Victoria made at Arlington Farm, Rosslyn, Virginia, in 1930 by F. A. Coffman. Warner also selected Quincy Gray C. I. 4078, also known as Quincy 2 and Quincy white, from the cross (Victoria x Norton) x Red Rustproof. This cross was made about 1931 by S. J. Hadden at the Georgia Agricultural Experiment Station. In the fall of 1940, seed of Quincy Red and Quincy Gray were released to three growers in Gadsden County and one grower in Jackson County. The impetus of these two varieties resulted in purchase of one or more combines in nearly every county in north Florida. In Gadsden County the number increased from one in 1940 to fourteen in 1942.

Quincy Red and Quincy Gray were followed by Florilee, which was first distributed in the fall of 1943. This variety was selected by J. D. Warner from the cross Lee x Victoria made by T. R. Stanton in 1931. By 1945 the yield nurseries contained a large number of Victoria and Bond derivatives, which were the highest yielding entries in the variety tests. This is in contrast to the period prior to 1939 when the Red Rustproof types were the highest yielding entries. In 1945 seventy acres of seed production fields at the North Florida Experiment Station were planted with four varieties having the Victoria type of crown rust resistance. This indicated the popularity of these varieties in north Florida.

[4]C. I. refers to Cereal Investigation numbers assigned to oat varieties by the Division of Cereal Crops and Diseases, BPISAE, USDA.

In 1936 J. P. Camp, at the Main Station, Gainesville, crossed Bond with Fulghum and obtained Florida 167 which was released in 1942. This variety was early maturing and highly resistant to crown rust and by 1945, production in Florida had increased to six thousand bushels. At Gainesville it had been observed that early maturity was associated with high grain yields and that Quincy Red, Quincy Gray, and Florilee were not as well adapted to that area as Florida 167.

In 1945 farmers in the section of Florida suitable for oat production had a choice of four high-yielding varieties utilizing two distinct sources of crown rust resistance. As a result, the production increased from 154,000 bushels in 1940 to 900,000 bushels in 1945. The crop was filling a definite need in the agricultural program as a source of grain and winter grazing.

The susceptibility of Victoria derivatives to Victoria blight (13) was discovered in 1946 and the new species *Helminthosporium victoriae* M. and M. was described (9). In 1946 and 1947 this disease caused a drastic reduction in the productiveness and quality of Quincy 1, Quincy 2, and Florilee. Yield records of these varieties at the North Florida Experiment Station illustrate the devastating effect of Victoria blight. For the 6-year period 1941-1946 Quincy 1, Quincy 2, and Florilee averaged 47, 45, and 51 bushels per acre, respectively; in 1947 the same varieties produced only 10, 11, and 14 bushels per acre.

The severe epidemic of Victoria blight brought about a rapid shift from Victoria derivatives to blight-resistant varieties of Bond origin such as Florida 167 and Camellia, and Red Rustproof strains such as Rustproof No. 14, Hastings 100 bushel, Bancroft, Appler, Nortex, and Texas Red Rustproof. However, in 1948 most of these varieties were severely damaged by crown rust (race 45 and similar races).

The sudden outbreak of these two diseases explains the decrease in production of oats in Florida from 900,000 bushels in 1945 to 228,000 bushels in 1949. Although no actual data are available, a similar reduction in grazing value was apparent. In 1948 no single advanced, agronomically-acceptable strain or variety had combined resistance to these prevailing oat diseases. Severe epidemics of Victoria blight and crown rust made yield determinations impossible, but afforded unusual opportunities for selection for disease resistance.

The disease situation in Florida, together with those in other sections of the Southeast, probably influenced the allocation of research and marketing act funds in 1949-1950 for pathological research. The location of a regional small grain pathologist in the plant Pathology Department at Gainesville made possible research on diseases of small grains, which was needed as a basis for a more efficient and enlarged breeding program. Disease nurseries and laboratory tests with diseases not adapted to field testing were used to supplement mass testing of lines in breeding nurseries. This afforded a team approach, with close coordination between the plant pathologist and plant breeders at Gainesville and Quincy.

A selection from the cross (D 69 x Bond) x Fultex, made in 1941 by H. C. Murphy of the United States Department of Agriculture and the Iowa Experiment Station, gave evidence of having resistance to Victoria blight and moderate resistance to crown rust in 1948. After being tested in the greenhouse for Victoria blight resistance, one-half pound of seed was sent to the Agricultural Experiment Substation at Aberdeen, Idaho, for a summer increase. In 1949 both grain and forage yields were outstanding, and further increase plantings were made. In 1950 this selection

was named Southland (1) and approximately 10,000 bushels was released by the Experiment Station. This variety was immensely popular for grain and forage in Florida and adjacent Gulf Coast areas. As a result, oat production in Florida increased from 288,000 bushels in 1950 to 1,080,000 bushels in 1952.

At the time Southland was released it was resistant to prevalent races of crown rust. As a result of widespread acceptance of Southland, a large majority of the oat acreage in Florida was planted to this variety. This likely explains the fact that 35 percent of the rust collections from Florida in 1951 were of races to which Southland was susceptible. This striking change in the rust race picture in Florida has been coincidental with the shift to varieties susceptible to races which at one time were of minor importance.

The presence of races of crown rust which attack both Bond and Victoria in Florida focused interest on Landhafer and Santa Fe, two crown rust resistant varieties introduced from Germany and Argentina, respectively, by H. C. Murphy and associates at Ames, Iowa. Hybrids involving Landhafer and Santa Fe were received from the United States Department of Agriculture in 1948, and in 1949 numerous crosses involving these varieties were made in Florida. In 1950 selections from Minnesota which were resistant to crown and stem rust were used in the crossing program.

In the United States the first derivatives of Landhafer were released to farmers in Florida. Floriland (2), released in 1952, was selected from the cross Florida 167 x Landhafer, and Sunland (10) released in 1953 from the cross Fulghum C. I. 708 x Landhafer. The second Santa Fe derivative released in the United States was Seminole (10) which was selected from the cross Appler x (Clinton^2 x Santa Fe) and released in Florida in 1953. All three of these crosses were made by F. A. Coffman of the United States Department of Agriculture in 1947. Floriland proved to be a valuable forage oat and Seminole was excellent for grain production. Sunland never equaled either of these two varieties for either forage or grain production.

The utilization of Floriland, Sunland, and Seminole having the crown rust resistance of Landhafer and Santa Fe lessened the damage from this disease during the period 1952-1957. Stem rust however continued to be a threat. Each of the varieties recommended for commercial production in Florida was susceptible to at least one of the major oat diseases likely to be encountered. Crown rust resistance from Landhafer and Santa Fe and also stem rust resistance had been added to early generation selections from Southland crosses. In addition, several diverse sources of crown rust resistance such as Uregland, Silva, Ascencao, and plant introductions such as C. I. 7171 and C. I. 7172 were used to broaden the germ plasm base of the breeding nurseries.

When Floriland and Sunland were released, variability in seed type was noted by the State Seed Laboratory. Off-type kernels presented a problem with certification or registration. Extensive plantings of panicle rows indicated that rather accurate identification of variatal mixtures could be made (e.g., Southland in Floriland or Sunland). However, seed that were variable in such characters as awns, basal hairs, or sucker mouths produced seed with variable characteristics. Evidently the variability was due to the genetic instability of *Avena byzantina* and many of its derivatives.

Studies were initiated to evaluate methods of determining forage yields

of experimental lines. Clipping with an 8-inch paring knife using a "guide board" to insure cutting at the same height (19) was found to be a suitable method for evaluating experimental lines and the many variables that affect forage production. The optimum plot size for clipping tests was found to be one row eight feet long, with four or five replications to provide a suitable degree of accuracy. Scoring is based on a visual estimate of forage yields. A correlation of 0.72 was obtained between the accumulative forage scores in one experiment and the accumulative clipping weights in another experiment. These data suggested that scoring was satisfactory for a rough estimation of forage production of experimental lines.

In 1956 a severe epiphytotic of oat mildew (*Erysiphe graminis* var. *avenae* El. Marchal) occurred in the breeding nursery in Quincy. Reactions were determined for a total of 250 varieties and selections. This disease did not severely reduce grain yields when disease development was arrested prior to the early heading stage of the host. However, forage yield was affected by the disease (16).

When Southland was released, some lodging due to a condition of undetermined origin was noted. A new oat disease was described in 1951 (5) which was caused by a new Helminthosporium similar in morphology to *H. victoriae* and *H. sativium* but more closely resembling the latter. The disease was referred to as culm rot. Physiological specialization of the fungus *Helminthosporium sativium* Pan; King and Bakke was noted. It was already evident that additional resistance to culm rot was necessary in commercial varieties.

During the spring of 1956 a severe epiphytotic of oat leaf blotch (*Helminthosporium avenae* Eidam) occurred in Florida and south Georgia. A new disease manifestation (sheath and culm infection) was observed and described (7) in 1957. Studies showed that certain cultures exhibited a tendency toward physiologic specialization. Symptoms expressed by Southland inoculated with two isolates were distinctly different, thus indicating the occurrence of symptomatological strains of H. avenae.

The crown rust situation once more became ominous in spite of the release of resistant derivatives of Landhafer, Santa Fe, and also Trispernia. Crown rust race 264 was found in North America as early as 1953 (15). This was a disturbing discovery since the only known source of resistance to this race at that time was diploid (7n) Saia. The race was not found in 1954 or 1955, but appeared again in 1956. Race 264 and 290, which attack derivatives of Landhafer, Santa Fe, Victoria, and Bond (16) were destructive at Quincy and Gainesville, respectively, in 1957. These races were present in the Gulf Coast area, and late in the season race 290 was prevalent on oats in areas of the corn belt and upper Mississippi valley. One of the approaches to this problem was the extremely difficult task of transferring crown rust resistance from diploid species (7n) to hexaploid (21n) or cultivated varieties.

In 1958, 2,318 entries of the active world collection were grown in Quincy and inoculated with crown rust races 202, 216, 264, and 290. Approximately 10 hexaploid entries were resistant to both races 264 and 290. Red Rustproof entries of the active world collection were late rusters when inoculated with a composite collection of the new and virulent races of crown rust.

In 1957 a rather large F_2 population of the cross C. I. 7172 x (0-200-10 x Southland) made at Quincy in 1955 contained numerous plants with

mature plant resistance to a heavy natural infection of the Landhafer attacking races of crown rust. In 1959 approximately 1,600 early generation and advanced selections were tested in the greenhouse for seedling reaction to crown rust races 203, 216, 264, and 290 and stem rust race 7A. Certain lines involving C. I. 7171 and C. I. 7172 were found to have combined resistance to the prevalent races of crown rust as well as to the Landhafer attacking races and stem rust 7A. A few lines exhibited an immune reaction in contrast to a resistant reaction commonly found in material having protection from the Landhafer races. They were evaluated for plant type and adaptability (8), and were considered as some of the most promising breeding material available to southern oat breeders.

Radiation as a plant-breeding tool was outlined (17) in 1930. Since 1950 there has been a renewed interest in radiation in the United States, especially because of the possibilities of inducing mutations for disease resistance. Workers have reported that the mutation frequency of genes affecting disease resistance in small grains is increased by radiation.

In the spring of 1954 Floriland was irradiated in an effort to improve the undesirable kernel characteristics and at the same time induce resistance to stem rust race 7A. Extreme variation was observed in morphological characters and pathological reaction in progenies from these irradiated Floriland oats (4). When inoculated with crown rust race 264 under greenhouse conditions, a mesothetic reaction and a distinct mature-plant resistance were observed. In 1958 and 1959 several lines showed excellent mature-plant resistance to race 264 in specialized rust nurseries at Isabela, Puerto Rico. These selections also appeared resistant to race 290 at Quincy and Isabela in 1959.

Approximately 75 head rows of irradiated Floriland selection AB 180 were bulked and increased at Aberdeen in the summer of 1958. Seed supply was sufficient for yield testing at several locations. An increase block was also planted at Quincy in the fall of 1958. Grain yields were quite satisfactory. The bulk selection is uniform and has excellent protection from the Landhafer races of crown rust. Seed is being turned over to the Florida Seed Producers Association for further increase. This selection will be available to the farmers in Florida in 1960.

Cytological examinations indicate that chromosome bridges and micronuclei exist in these irradiated lines. Also, a high degree of sterility was present, which is conducive to outcrossing. The wide variation could have resulted from successive outcrossing together with numerous chromosome aberrations. This combination seems more likely than successive outcrossing alone. These studies indicate that considerable genetic change was induced by irradiation.

The use of radiation to produce genetic changes is a new tool of potential value in agriculture and is capable of being used as a supplement to regular breeding procedures. There is a great need for better understanding of the fundamental processes of gene mutation and for a refinement in techniques of finding desirable variants. It is not a panacea that can be expected to revolutionize oat breeding, but is worthy of much more intensive investigations.

WHEAT

For the past twenty years breeding has been limited; however, an extensive testing program is conducted. The yield tests include varieties and selections of soft winter wheat which are possibly adapted to Florida.

Coastal and Coker's 47-27, two varieties released by the Coker's Pedigreed Seed Company, Hartsville, South Carolina, have been moderately resistant to leaf rust (*Puccinia rubigo—vera tritici* Eriks. and Henn.) in commercial plantings. In recent years the Bledsoe variety has been grown extensively. This variety was released by the Georgia Agricultural Experiment Station and is moderately resistant to leaf rust and powdery mildew (*Erysiphe graminis tritici* El. Marchal). A commercial variety should have resistance to both these diseases.

RYE

Rye has probably been grown in Florida for at least 50 years. Until 1956 Florida Black was the leading variety. Also, numerous strains of Abruzzi were grown to some extent. In the variety trials these strains were nearly always inferior to Florida Black in grain and forage production.

In 1948-1949 approximately 150 strains of rye introduced from Uruguay, Argentina, Brazil, Austria, India and Turkey were grown at Gainesville, Florida. Fourteen of the introductions from Uruguay, Brazil, and Argentina appeared to have sufficient disease resistance to be used in a breeding program. One plant was observed to be free of leaf rust (*Puccinia rubigo—vera secalis* Eriks. and Henn.), stem rust (*Puccinia graminis secalis* Eriks.), and powdery mildew (*Erysiphe graminis secalis* El. Marchal). Seed from this plant was increased in 1951. Subsequent selection and testing resulted in the release of Gator rye (3) for seed production in 1956. A high percentage of Gator plants is resistant to leaf rust, stem rust, and mildew. This variety is widely grown in Florida, Georgia, South Carolina, and other areas of the Gulf Coast region.

Experiments have suggested that utilization of hybrid vigor would significantly increase forage production. Hybrids involving 28 combinations of nine varieties of rye produced 15 percent more forage than the parents (20). Average production of the hybrids ranged from 95 percent to 132 percent of that of the parents; specific combinations ranged from 73 to 170 percent. A gametocide, a, b, dichloroisobutyrate, was sprayed on rye at two concentrations when the plants were at four levels of maturity. None of the treatments inhibited pollen production. Another approach is to induce male sterility by transferring the chromosomes of rye to wheat cytoplasm. The first backcross progeny exhibited, in pollen fertility tests, 9.5 percent fertility in comparison to 1.1 percent fertility of the F_1's. Irradiation experiments utilizing six doses of gamma rays have been started in an attempt to induce mutations in the self-sterility allels in rye.

SUMMARY

Crown and leaf rust have long been the most serious diseases of small grains in Florida. During the past ten years there have been three almost complete changes in the prevalent races of crown rust in Florida. Breeding programs have been directed toward control, through genetic resistance, of the prevailing races. Diverse sources of resistance have been utilized in the breeding programs. A bulk selection derived from irradiated Floriland has shown resistance to crown rust races 264 and 290 under widely different field conditions. The selection is uniform and will likely be available to farmers in 1960. Past records suggest that no variety of oats will likely remain resistant to crown rust longer than five years.

In recent years additional information and breeding stocks resistant to diseases other than crown rust has made possible breeding for resistance to diseases such as oat leaf blotch and culm rot.

The possibility of utilizing hybrid vigor to increase forage production of rye is being investigated.

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A History of Field Corn Breeding in North Florida[1]

E. S. Horner[2]

The foundation of the Florida field corn breeding project was laid in 1924 with the initiation of corn variety testing at Gainesville. Entries in these early tests consisted mainly of Florida farmers' varieties, which were single eared, and prolific strains from neighboring states. While the native Florida varieties proved highly resistant to rice weevil damage, the best of them were 15 to 30 percent lower in yield than the prolific strains (1). It was on the basis of these results that the first emphasis in the corn breeding program, initiated in 1927, was to combine prolificacy and high yield with weevil resistance. Since hybrid corn was still in the experimental stage, breeding was directed toward development of improved open-pollinated varieties as well as hybrids.

EARLY RESULTS WITH HYBRIDS

The first hybrid to be released (in 1941) was Florida W-1, a prolific white hybrid with good weevil resistance. During the period 1938-1947 this hybrid produced 20 to 25 percent higher grain yields than Whatley Prolific, one of the highest yielding open-pollinated varieties available.

The four parent inbred lines of Florida W-1 were among the best of approximately 10,000 lines in which inbreeding was started during the first four or five years of breeding. After several years of selection and top-cross testing, only about 50 lines remained from the original 10,000 self-pollinations. Each of these lines had one or more serious faults; so a second cycle of breeding was started, using various combinations of the first cycle lines as source material. A good number of the second-cycle lines were definitely superior to any of the first group with respect to vigor and other characteristics. However, hybrids between the new lines in various combinations were on the whole not significantly higher yielding than the first cycle hybrids (2). This disappointing development led Hull (2, 3) into a re-evaluation of corn breeding methods, as will be discussed later on.

The second major step forward in the hybrid corn variety picture came in 1948 with the release of Dixie 18 by the Georgia Coastal Plain Experiment Station. This is a high-yielding yellow double-cross hybrid [pedigree: (F44 x F6) . (GT112 x L578)] which makes use of two second-cycle Florida lines, F6 and F44. It produced 17 percent higher grain yields than Florida W-1 in station tests from 1947 to 1949, had significantly better standability than W-1 (10 percent *vs.* 42 percent lodged plants in 1949), but was less resistant to weevil infestation (40 percent weevily ears *vs.* 30 percent for W-1). Because of its higher yield, better standability and yellow kernel color, Dixie 18 rapidly replaced W-1 in north Florida and the Southeastern Coastal Plain area. In 1959 it was still the most widely grown hybrid in Florida and is the standard against which new hybrids must be judged. Although several excellent hybrids have been released

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by different breeders recently (including Florida 200, Jackson, Lee, Coker 67, Coker 71 and Coker 811), there has been no new "breakthrough" in yield levels since Dixie 18 was introduced.

The impressive increase in corn production per acre in Florida since 1950, Figure 1, can be attributed in large part to the combined direct and indirect benefits of improved hybrids. Only 13.5 percent of the acreage was planted to hybrids in 1948, but by 1958 this figure had increased to 89 percent (5). During the same period average corn yields in Florida rose from 11 bushels per acre to 26 (4). This large gain in yields was due in part to the direct benefit of hybrid seed, because the best hybrids produce about 40 percent more than the best open pollinated varieties. However, the indirect benefit of hybrids probably was of greater importance—farmers are more willing to fertilize properly and plant thicker stands with hybrids because they respond to good treatment better than the old varieties. Also, farmers are inclined to use better cultural methods with hybrids because they have an investment of about $1 per acre in seed to protect.

Although farm yields have been increased in recent years, there is still room for improvement. During the past 10 years, yields of Dixie 18 and other leading hybrids have averaged nearly 60 bushels per acre in Experiment Station tests at several north Florida locations. This has been done without irrigation on soils that are fairly representative of the corn-growing areas. Fertilization levels with these tests have been moderate—equivalent to about 500 pounds per acre of 4-12-12 per acre with an additional nitrogen application (side-dressing) of about 60 pounds per acre. An important factor in obtaining good yields is in getting enough plants per acre to make full use of the fertilizer that has been applied. Experiment Station variety tests now are conducted at 7200 to 9600 plants per acre—equivalent to 18" to 24" between plants in 36-inch rows. This is in contrast to 36" between plants in 60-inch rows (2900 plants per acre) that was the standard planting rate for variety testing at Gainesville twenty years ago. Many farmers still do not obtain good enough stands to obtain

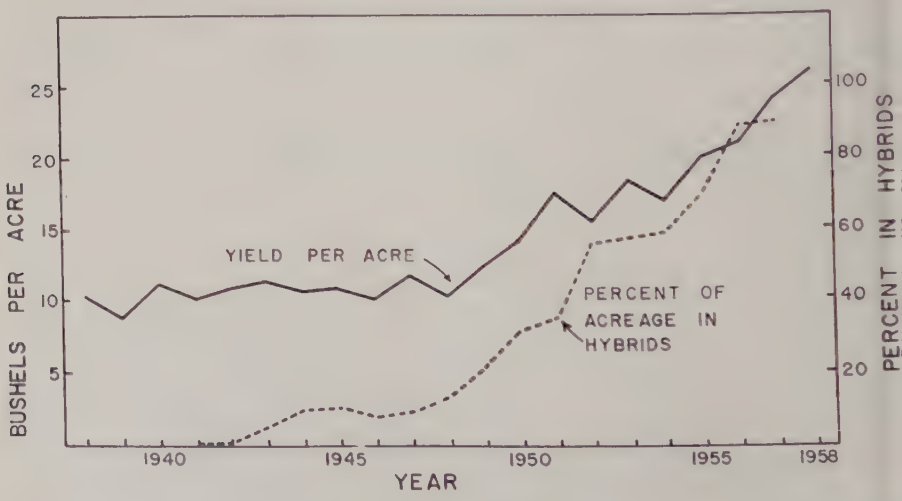

Figure 1.—Trends in average yield per acre and percent of acreage in hybrids in Florida, 1938–1958.

satisfactory yields, although there has been marked improvement in this respect during the last ten years.

DEVELOPMENT OF NEW BREEDING METHODS

Methods followed in the corn breeding program at Gainesville until about 1945 were very similar to those used in the main Corn Belt and other parts of the country. The first step in developing a hybrid was to select within and among lines during inbreeding for important characteristics such as vigor, disease and insect resistance, and kernel quality. This was followed by top cross tests to determine which lines produced the best hybrids in general combinations (general combining ability). The third step was to intercross the best general combiners in all possible combinations, in order to determine which specific crosses were most desirable with respect to yield and other traits (specific combining ability). From this information one could predict which combinations of single crosses would produce the best double crosses. In brief, the conventional method placed more emphasis on selection for *general* than on *specific* combining ability. This was justified on the belief that hybrid vigor in corn is due primarily to the action of a large number of favorable genes showing partial or complete dominance. If the above theory is correct, the important consideration in breeding would be to accumulate as many dominant genes in the inbred lines as possible by recurrent selection for vigor and general combining ability. The only barriers to fixation of hybrid vigor in inbred lines would be the large number of loci involved and linkage between favorable and unfavorable genes.

Second cycle lines developed at Gainesville were more vigorous and generally more desirable-appearing than the original lines, as was mentioned earlier. It seemed obvious that they carried a higher frequency of dominant favorable genes than their progenitors and therefore were expected to produce higher yielding hybrids. Since this expectation was not fulfilled, Hull (2, 3) concluded that specific combining ability was much more important than had been supposed. In other words, selection for hybrid vigor in specific combinations from the beginning might be more fruitful than the usual procedure of eliminating lines with poor general ability before testing specific combinations. Further study led Hull to the conclusion that heterozygosity *per se* was more important to hybrid vigor in corn than the overall frequency of dominant favorable alleles. He coined the word "overdominance" to describe the situation in which the heterozygous locus (Aa) contributes more to the expression of a character than either homozygote (2 3).

In order to shift the emphasis to specific combining ability, it was necessary to depart from the conventional method of breeding described earlier. Two important changes were proposed by Hull:

(1) A tester with a specific genotype, either an inbred line or a single cross, replaced the general tester which had a broad genetic base.
(2) The inbreeding phase was made much shorter, allowing more frequent cycles of selection for combining ability with the specific tester.

This new method was called "recurrent selection for specific combining ability," which is a good description of what takes place. Briefly, a cycle of

breeding consists of crossing a number of S_0 plants or early-generation inbred lines with the tester; growing the test crosses in yield trials while holding selfed seed of the parent plants or lines in storage; and intercrossing the best parent lines, based on test cross performance, to form a new crossbred population which is the foundation of the next cycle. The same tester is retained cycle after cycle, and commercial utilization of the resulting populations normally would be accomplished by releasing hybrids between the tester and lines derived from a recent cycle of breeding.

The concept of frequently recurring cycles of selection (recurrent selection) was introduced because there appeared to be no particular benefit from inbreeding several generations before making test crosses. The majority of loci in a line are fixed after one or two generations of selfing, and there is relatively little opportunity for effective selection with additional inbreeding. Therefore, time is saved and the multiplicative effect of recurrent selection is taken advantage of to the fullest when breeding cycles are made as short as possible consistent with adequate evaluation and recombination of selected lines. The minimum number of generations required per cycle is three, but it is possible that longer periods would be desirable in order to test the hybrids for more than one season and to more thoroughly "mix" or recombine the selected lines.

RESULTS WITH RECURRENT SELECTION FOR SPECIFIC COMBINING ABILITY

Experiments to test the merits of the new breeding procedure, recurrent selection for specific combining ability, were initiated in 1946. In the first experiment the seed parent of Fla. W-1, F1 x F2, was used as the tester. Two cycles of selection were completed by 1951, when it was decided to drop this experiment in favor of a similar one that utilized the seed parent of Dixie 18, F44 x F6, as the tester. The latter test was initiated in 1949 and has now reached the fifth cycle of selection. Test crosses between S_0 plants and the tester were tested for one season in the first three cycles, and in the fourth cycle they were tested for two years. The tests were conducted at two to four locations in north Florida—usually at Gainesville, Quincy and Jay. The results are shown graphically as frequency distributions of test cross means in Figure 2. The different cycles are compared by means of the Dixie 18 check, which was represented by several plots in each replication. The mean yields of grain for all test crosses in successive cycles in percent of Dixie 18 were 93, 95, 107 and 106 for the first four cycles. These figures indicate that gains have been made; however, the gains have not been consistent from cycle to cycle according to this test. Another test of progress in this experiment was made by making bulk hybrids of the products of the first three cycles with the tester:

Hybrid	Bushels Per Acre
Tester x Syn. I	52
Tester x Syn. II	54
Tester x Syn. III	60
Dixie 18 check	54
L.S.D. (.05)	4

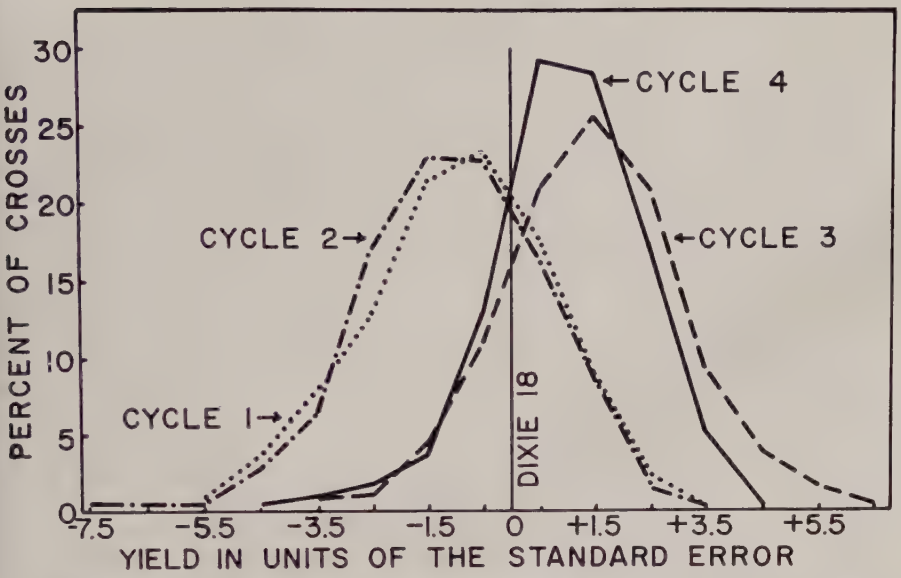

Figure 2.—Comparison of test cross means relative to the Dixie 18 check in different cycles of recurrent selection for combining ability with F44 x F6.

These results indicate that consistent gains were made through the first three cycles. Since the three cycles were evaluated in the same year, the latter test is probably a more reliable one than that shown in Figure 2, where data from different years are compared.

Another approach to recurrent selection for specific combining ability has been to use the crossbred population from the third cycle of the above experiment as a tester. This was done to allow improvement on the seed parent side as well as the pollinator of such hybrids as Florida 200 and Dixie 18. Two new groups of lines were crossed with this population (Syn. III), and each group of test crosses were grown at three locations in 1958. Yields relative to Dixie 18 were somewhat higher than had been expected on the basis of previous experience with new lines, Figure 3. In each test the average yield of the Dixie 18 check plots was below the mean of the whole group. Two conclusions might be reached concerning these results: (1) The crossbred population used as the tester has good general combining ability, even though it is the result of selection for specific combining ability with F44 x F6; and (2) a number of the lines have excellent breeding potential. There appears to be a good opportunity for building up specific combining ability with additional cycles of selection to a higher level than is now available.

Results from the experiments described above indicate that recurrent selection for specific combining ability will be successful. Significant increases in yield have been made and there seems to be good opportunity for additional gains. However, it is not clear at this time how much of this increase is due to better specific combining ability (between the tester and the selected population) and how much is due to improvement in the general combining ability of the selected populations. Additional tests to evaluate this point are in progress.

SUMMARY

The field corn breeding program for north Florida was initiated in 1927 and has been carried on continuously since that time. It has been successful both in producing useful inbred lines and hybrids and in the more theoretical field of developing improved breeding methods. The hybrid Dixie 18, by far the most successful and widely used hybrid ever released in the South, contains two Florida lines, F6 and F44. Dixie 18 and other more recent hybrids produce on the average about 40 percent higher grain yields than the best open-pollinated varieties.

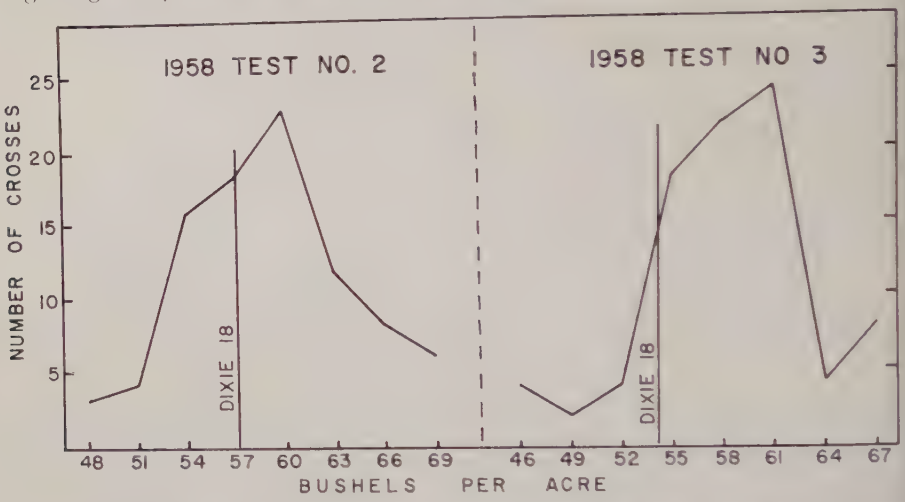

Figure 3.—Frequency distributions of test cross means in tests where Syn. III was the tester.

The contributions made by Dr. Hull to the understanding of hybrid vigor in corn have more long-range significance, however, than the practical developments just mentioned. His work has stimulated interest in this field at other institutions, both in this country and abroad. A considerable amount of work has been done, or is in progress, to test the theory of overdominance and the new breeding procedure, recurrent selection for specific combining ability. Results to date in Florida indicate that yield levels can be increased appreciably with this method. However, these experiments have not progressed far enough yet to permit an evaluation of the relative importance of specific and general combining ability. Where a single cross tester was used, present data indicate that both general and specific combining ability were improved.

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Soybean Breeding in Florida[1]

Kuell Hinson[2]

Research on soybeans began in Florida at a time when the crop was grown in the United States almost entirely for forage. Varieties and plant introductions were evaluated in Florida primarily for forage production, but attention was also given to seed production as a means of propagating the crop locally. Soybeans never became an important forage crop in the State, and research on soybeans for forage was discontinued. It was not until new varieties were developed for use as an oilseed crop that soybeans found a place in Florida's agriculture. Varieties and breeding lines developed in other States for seed production have been tested since 1949 in the regional variety testing program for Southern States. A breeding program was started at Gainesville in 1955 to develop varieties better adapted for seed production in the State.

EVALUATION AS A POTENTIAL FORAGE CROP

Research on soybeans for forage began in Florida in 1925 and continued through 1938 (1). In 1925 eight varieties were planted in nine counties in north and west Florida. Otootan and Biloxi were the outstanding varieties for forage production, but few or no seeds were produced by any of the varieties tested. In 1927 the work was expanded at Gainesville to include date of planting and inoculation tests "looking toward seed production." Research was continued on date of planting and variety tests until 1935, with additional varieties and plant introductions being incorporated in the variety testing program. No significant progress was made on the problem of seed production. The highest yielding forage varieties were evaluated for their silage qualities in tests beginning in 1929. The conclusions were that "soybeans made silage of good quality palatable to the cows." Biloxi yielded 8.87 tons of silage per acre in 1930 and 4.57 tons per acre in 1931. The silage experiment was concluded in 1931 and the results published in 1932 (2).

In 1934 work was initiated at both the Everglades Station at Belle Glade and the North Florida Station at Quincy. Both stations tested many of the available varieties and plant introductions. The emphasis at the North Florida Station was on a forage variety with good seed-producing qualities. Luxuriant growth was reported, but many of the varieties tested did not yield sufficient seed for replanting the following year. In 1936 a range in yield from 5 to 12 bushels per acre was reported for 50 varieties tested for two years. Diseases were thought to be the limiting factor in seed production in north Florida.

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At Belle Glade, soybeans were evaluated for their value as a forage, cover, and green manure crop. It was necessary also to consider seed production in order to perpetuate the crop economically from year to year. Tests were conducted to determine the influence of planting date on both forage production and seed yield. The highest seed yield reported at Belle Glade was from the Otootan variety, which produced 30.5 bushels per acre in 1938 when planted August 11 and harvested December 10. Work on soybeans for forage was finally discontinued, as other crops proved more promising.

The early research work failed to establish soybeans as a crop for any region of Florida. A major reason for the failure seems to have been unsatisfactory seed production. Looking at the problem in retrospect, it now appears that poor seed production was due to one or more of the three following reasons. (1) Photoperiod response, mineral nutrition and soil pH requirements were not understood well enough to enable the various research men to use the best cultural practices. (2) The varieties and introductions used were genetically poor seed producers, as has been demonstrated by recent tests using the best known cultural practices. (3) Insects, particularly stinkbugs, were probably more of a problem than was recognized at that time. Stinkbugs puncture the pods and suck plant sap from the developing seed. Punctures occurring early in seed development may cause the entire pod to drop, and those occurring later will result in the production of poor quality seed.

ACCEPTANCE AS AN OILSEED CROP

Soybeans were not processed extensively for oil and meal in the United States until 1929, and it was not until 1935 that about half the domestic production was processed. In 1949 more than 88 percent of the soybeans were processed, the remainder being used mainly for seed. Production increased from 23,157,000 bushels in 1934 to 230,897,000 bushels in 1949 (3). Since 1949 production has more than doubled, reaching a peak of 574,000,000 bushels in 1958.

The increased demand for soybeans as a seed crop resulted in the establishment of breeding programs to develop varieties for seed production with little or no emphasis on their forage value. Several new varieties were developed, some of which had a limited adaptation as far south as Florida. Although records are not available, the first significant production in the State probably occurred in west Florida largely through the influence of a concentrated area of production in the adjacent section of Alabama. It was not until 1949 that sufficient acreage was grown to be included in crop production statistics. Eight thousand acres were planted in 1949, and since that time the acreage has increased to the present 45 to 50 thousand acres. The acreage trend in Florida since 1949 is shown in figure 1. The average yield per acre in Florida is compared with the national average in Figure 2.

Most of the acreage is planted in rather concentrated areas in the State. For the past few years, Escambia County has planted over 15,000 acres to soybeans which is more than is planted to any other field crop. From Escambia and Santa Rosa Counties, the crop spread throughout most of north and west Florida. The varieties adapted in that part of the State are not well adapted to the peninsula; consequently, few soybeans are

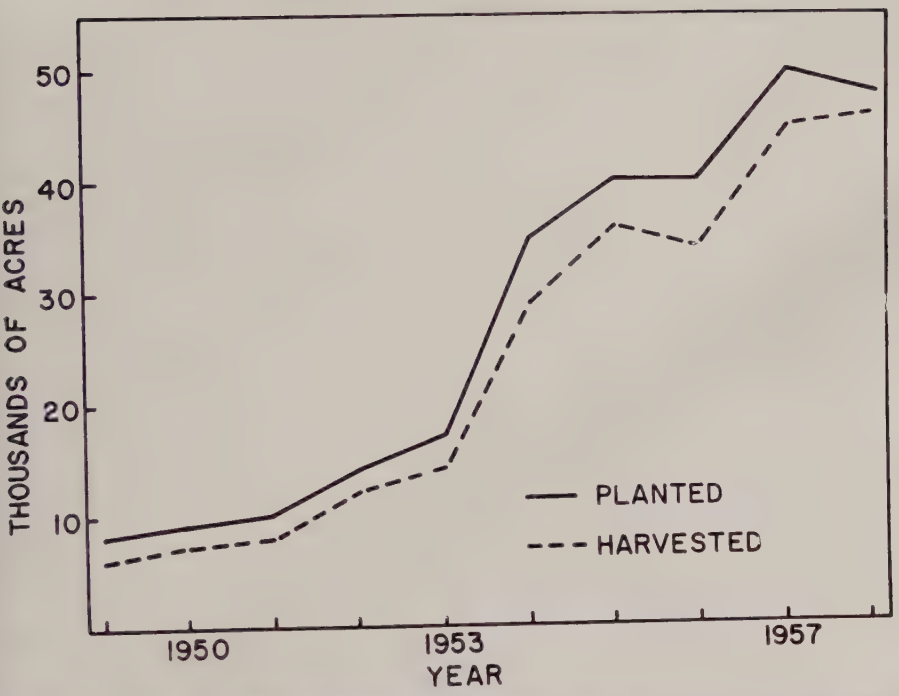

Figure 1.—Soybean acreage planted and harvested for beans in Florida from 1949 through 1958. (Adapted from Florida State Marketing Bureau Annual Agricultural Statistical Summary. 1959. p. 139.)

grown in the peninsula except in Dade County, where the Improved Pelican variety has given satisfactory results. Dade County started production with 200 acres in 1955, and by 1958 this had increased to 15,000. The 1959 acreage was not as large, but there is a potential of much more than 15,000 acres for soybeans in Dade County following winter tomatoes.

REGIONAL VARIETY TESTING PROGRAM

Florida began participation in the regional variety testing program for Southern States with tests at Gainesville and Quincy in 1943 and 1944. Plantings were made in early April without fertilizer and the plots were damaged by insects. Performance was unsatisfactory and it was concluded that soybean varieties developed for seed production were not adapted. However, after more varieties became available and work had been done in other states to develop better cultural practices, soybeans were grown successfully and some of the varieties that had been tested in 1943 and 1944 performed satisfactorily. Variety testing was resumed in the regional program in 1949 and nurseries have been grown at the locations shown in Table 1 from 1949 through 1959.

Because of their sensitivity to photoperiod, soybean varieties are adapted to relatively narrow belts from north to south. For convenience, the various varieties, breeding lines, and introductions have been assigned to maturity groups 0 through 8 to identify their relative maturity and range

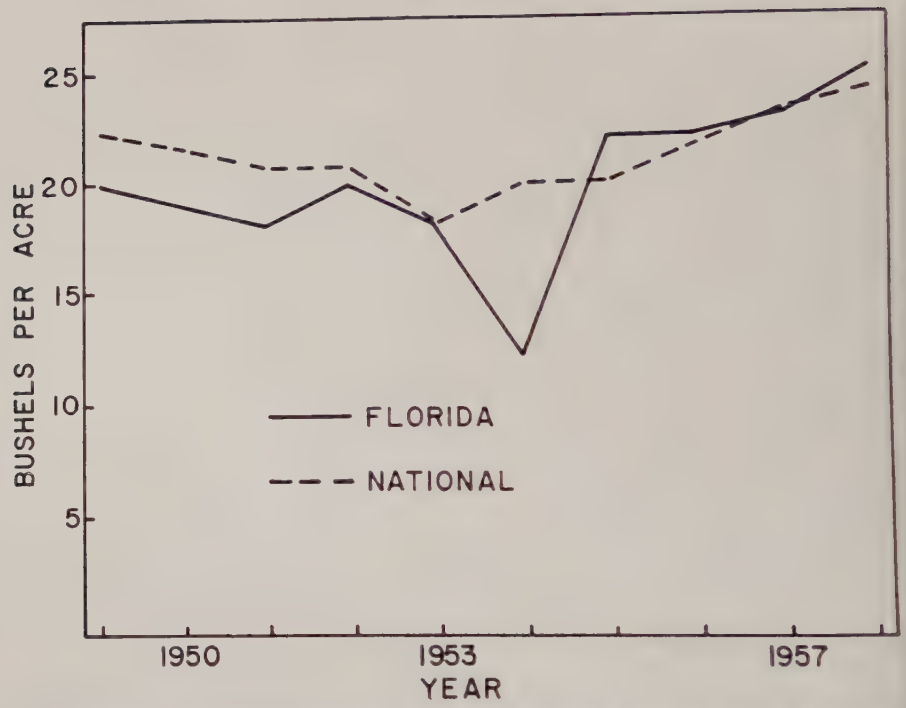

Figure 2.—Average yield of soybeans per acre in Florida compared with the national average. (Adapted from The Soybean Blue Book. 1959. pp. 18, 23.)

of adaptation. Maturity group 0 is adapted in southern Canada and the northernmost areas of the United States. Maturity groups 7 and 8 are adapted in the Gulf Coast and South Atlantic areas. The leading varieties in north and west Florida, Lee and Jackson, are in maturity groups 6 and 7, respectively. Average maturity dates over a four year period at Gainesville are October 13 for Lee and October 22 for Jackson. Improved Pelican is in group 8 and has an average maturity date of October 28 at Gainesville. Each uniform regional nursery* usually consists of the two leading varieties of that maturity group for checks and 10 breeding lines considered most promising for future varieties. The uniform preliminary nurseries are grown at fewer locations and usually are made up of 34 breeding lines and two check varieties.

Two varieties adapted for production in the State have been released through the regional program since Florida began participating actively. Jackson was released in 1953 and Lee in 1954. Each had been tested for three years in its respective regional nursery before being named and released. Since adaptation was demonstrated in the regional nurseries, a proportionate share of breeder seed of each variety was made available for increase in the State, insuring Florida farmers of adequate seed supplies

*Uniform regional nurseries contain the same varieties, have the same plot size and are replicated the same number of times in a number of tests throughout a region. For example, the uniform regional nursery of maturity group 7 was grown at 27 locations in 10 states in 1958.

TABLE 1.—LOCATION OF UNIFORM REGIONAL NURSERIES IN FLORIDA FROM 1949 THROUGH 1959.

Location	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Davisville	7,8[1]										
McKinnonville		6,7,8									
Walnut Hill			6,7,8	6,7,8	6*,7,8	6,7,8	6,7,8	6*,7*,8	6*,7*,8	6*,7*,8	6*,7*,8
Jay	6,7	6,7,8	6,7,8	+	6,7,8	6,7,8	6,7,8				
Marianna		6,7,8	6,7	6,7	6,7	6,7	6,7	6,7	7	7	7
Quincy		+	6,7,8	6,7,8	6,7,8	6,7,8	6*,7*,8	6,7*,8	6,7*,8	6,7*,8	6,7*,8*
Monticello		6,7,8	7	6,7	6,7						
Gainesville				6,7,8	6,7,8	6,7,8	6,7*,8	6,7*,8	6,7*,8	6,7*,8*	6,7*,8*
Sanford				6,7,8	6,7,8	+	+				
Leesburg					6,7,8	+	+				

[1]Numeral refers to maturity group (see text).
*Preliminary nursery also grown.
+Nursery not harvested.

at the earliest possible date. Research personnel had grown both varieties for four years (three as a breeding line and one as a variety) and were able to make reliable recommendations to farmers when the first commercial seed became available.

BREEDING PROGRAM STARTED AT GAINESVILLE

A breeding program was established at Gainesville in 1955 in cooperation with the Agricultural Research Service, U. S. Department of Agriculture. The work was accelerated by obtaining from Stoneville, Mississippi, unselected F_2, F_3, and F_4 seed stocks from crosses which had been made to provide material for developing late-maturing breeding lines. All late-maturing genotypes in the germplasm collection, which is made up primarily of plant introductions but also includes old varieties and breeding lines, were grown at Gainesville to evaluate their possible utility in the breeding program.

The progress made in the breeding program can be measured best by comparing the performance of breeding lines with the best-adapted commercial varieties. Jackson has been the best-adapted variety in north central Florida over the entire testing period and has been the check variety in all tests of breeding lines. After the 1956 preliminary tests, 19 Florida lines and four selections from the germplasm collection were chosen for testing more extensively than the other selections that were to be retested. The 23 selections were the most promising breeding lines then available and were from diverse genetic backgrounds. They were tested at Gainesville and Live Oak in 1957 and 1958 to compare their performance with that of Jackson and to obtain information on the interaction of genotypes with years and locations. One old breeding line from the germplasm collection and five Florida lines were superior to Jackson in yield at the .05 level of significance. Yields of the "superior" lines ranged from 7 to 15 percent above the yield of Jackson. The highest yielding breeding line compares with Jackson as follows:

	Live Oak		Gainesville			
	1957	1958	1957	1958	1958*	Ave.
Jackson	20.1	31.0	32.9	38.9	27.0	30.0
F55-377	31.0	44.4	36.0	29.6	37.2	35.6

*Additional data from uniform preliminary 8 nursery.

A more critical comparison of lines in the maturity range adapted to peninsular Florida can be obtained from regional data. The 1958 regional test of lines in maturity group 8 contained 4 of the 19 lines in the 1957-58 tests in addition to three breeding lines from Louisiana and five varieties. Test plots were grown at 10 locations in the southeast, including three Florida locations. The four Florida lines ranked 1, 3, 8, and 9 in the array of means for all locations.

Nineteen Florida lines were included in the 36 entries in the regional preliminary test of lines in maturity group 8, which was grown at four locations. Nine of the 12 highest yielding lines were from the Florida program. The highest yielding line (F55-377) exceeded the Jackson mean by 16 percent. Although most of the uniform nursery tests were grown out-

side the State, the results are significant for two reasons: (1) the genotypes were measured over a wider range of environments than would be possible in local testing in one year, and (2) maturity group 8 contains the varieties and breeding lines that are best adapted to peninsular Florida. The highest yielding line in the tests at Gainesville and Live Oak in 1957 and 1958 is the same line that ranked first in yield in the uniform preliminary test of lines in maturity group 8.

Two of the 19 breeding lines were also tested in 1958 in the uniform preliminary test of lines in maturity group 7, the maturity group best adapted to north and west Florida. Tests were conducted at eight locations in the southeast, including three Florida locations. One line yielded significantly more than Jackson in the mean of all tests, had a significantly higher protein percentage, and did not differ in oil content. It was significantly higher yielding than Jackson at two of the three Florida locations but yielded lower than Lee, the second check variety, at Quincy. Comparative yields are presented below in bushels per acre:

	Gainesville	Quincy	Walnut Hill
Jackson	34.5	18.9	47.4
Lee	20.4	25.4	47.0
F55-822	44.1	22.7	53.1
LSD .05	8.3	3.0	8.1

The south Florida area requires a separate testing program because of its latitude. Plant height and photoperiod response are two of the more important considerations in the initial selection of lines for testing since vegetative growth is reduced as varieties are moved into areas which have shorter days during the growing season. Nurseries were grown at Homestead in 1958 and 1959 to compare the performance of selected breeding lines with Improved Pelican, the only variety now being grown in south Florida. Excessive rainfall reduced stands in 1958 to the extent that valid yield comparisons could not be made. In 1959 Improved Pelican ranked forty-first in one test of 44 lines replicated three times. Eighteen lines yielded more than Improved Pelican at the .05 level of significance and 10 yielded more at the .01 level. Although all lines made enough vegetative growth to shade out weeds in row middles, some were not tall enough for satisfactory mechanical harvest. Seed quality was poor in many lines, but in general the highest yielding lines had the most desirable height and seed quality.

The differences in soil type and water availability on the muck soils near Zellwood and Belle Glade as compared with mineral soils make a testing program necessary on muck soil to select the best adapted types. Cooperative work with the Central Florida Experiment Station has been underway near Zellwood since 1956 with the expectation that the results obtained will be applicable to the Belle Glade area. Experimental plots have been damaged by insects most years to the extent that critical yield data could not be obtained. In the successful tests, Lee and CNS-4 have been the best yielding commercial varieties, and a June 15 to June 30 planting date has resulted in the highest yields. Satisfactory evaluation of lines on muck soil will depend on better insect control. The cost of insect control in commercial plantings is not prohibitive; therefore, soybeans are yet a potentially important crop in both areas and breeding work will be continued at Zellwood.

The results presented are necessarily of a preliminary nature because of the short length of time a breeding program has been operating in the State. They are encouraging for all regions of the State, and lines entering the testing program more recently show promise of equaling or surpassing the performance of the earlier selections, particularly on mineral soils in peninsular Florida where maturity group 8 is adapted.

The increased yields indicated in the data presented here have been obtained by selecting for characters known or believed to be associated with yield in addition to actual selection for yield. Johnson et al. (4) have shown that as much progress can be made in selection for yield by selecting for combinations of characters that are associated with yield and have high heritabilities as can be made in selection for yield itself which has a low heritability. Hartwig and Johnson (5) reported that the foliage disease bacterial pustule (*Xanthomonas phaseoli* var. *sojensis* (Hedges) Starr & Burk.) reduced yields by 11 and 8 percent, respectively, at Stoneville, Mississippi, and Willard, North Carolina. Complete resistance to bacterial pustule is conditioned by one recessive gene pair (6) and is, therefore, easily obtained in breeding lines. Hartwig (7) has estimated that yield losses from target spot (*Corynespora cassiicola* (Berk. & Curt.) Wei) ranged from 18 to 32 percent in experimental plantings at Stoneville, Mississippi.

Bacterial pustule has occurred in epiphytotic proportions every year in experimental plots at Gainesville since the breeding program was started in 1955. Selection for resistance has resulted in practically all advanced generation lines being resistant. Target spot epiphytotics have been light to moderate until the 1959 season, allowing only the more susceptible genotypes to be discarded. In 1959 the incidence of target spot was much greater at all test locations. Lines previously considered moderately resistant were found to be susceptible. An indication of the effect of target spot on yield may be obtained from the results obtained from 43 lines grown in three replications at Homestead in 1959. None of the lines had been tested at Homestead previously; therefore, each may be considered a random sample for yield. Target spot ratings were made on a scale of 1 (highly resistant) to 5 (highly susceptible). The number of lines and average yield in each rating are presented below.

	Target spot rating				
	1	2	3	4	5
No. lines	14	10	11	8	0
Ave. yield	31.6	28.3	27.9	27.5	

The reduction in yield from target spot is not so great as Hartwig observed in Mississippi, but smaller differences should be expected since the most susceptible lines had previously been eliminated.

Johnson et al. (4) obtained genotypic correlations of +.22 and −.02 between height and yield in two populations, indicating little association between the two characters. However, their populations did not deal with the extremes in height encountered in the Florida breeding program. Observations over a period of years have suggested that determinate growth types that will attain heights of 36 to 48 inches under optimum growing conditions will produce maximum yields. The idea is supported by the performance of 29 F_4 lines selected from D49-2491 x Improved Pelican and 32 F_4 lines selected from D49-2491 x (D49-2491 x Improved Pelican).

D49-2491 is a determinate type and has many desirable agronomic qualities but is too early for this latitude because of its photoperiod response. Improved Pelican is a late maturing indeterminate type with fewer good agronomic qualities. Selection was for determinate growth type, height equal to or taller than Jackson, and resistance to bacterial pustule. Table 2 presents a comparison of the lines with their parents and Jackson as a check. The lowest yielding line exceeded the yield of the highest yielding parent by 13 percent; the mean yield of all lines exceeded the parental mean by 57 percent. The increased yield of breeding lines over parents is attributed to combining many of the desirable agronomic qualities of D49-2491 with a photoperiod response that allowed plants to attain more nearly optimum heights.

The results obtained from testing the same group of lines at Live Oak and Gainesville suggests that maximum use should be made of well chosen test locations in all regions of the State. In the five nurseries grown at both locations in 1957 and 1958, there was always a highly significant variety x location interaction for yield. However, only the group of lines that was referred to earlier as being selected for good performance and diverse genetic backgrounds was tested both years. The combined analysis of variance over years and locations is presented in Table 3. The highly significant varieties x locations interaction and the non-significant varieties x years interaction strongly suggest that more progress can be made in evaluating breeding lines by increasing the number of test locations than can be made by increasing the number of test years. Information has been received from the office of the State Climatologist to the effect that rainfall may be expected to vary as much between Live Oak and Gainesville (a distance of 75 miles) in any one year as may be expected at either location in succeeding years. This information plus the fact that differences in soil type often result in variety x location interaction has led to the establishment of a cooperative project to test large numbers of breeding lines at the Suwannee Valley Station, Central Florida Station (muck unit), and Sub-Tropical Station each year in addition to the tests at Gainesville.

FUTURE TRENDS

Breeding work in soybeans will continue to be directed toward the development of higher yielding varieties for all regions of the State. In the future, however, more emphasis will be placed on a higher protein content of the seed. Although considered an oilseed crop, the returns from

TABLE 2.—The Influence on Yield Resulting from Selection for Height and Growth Type as Indicated by Data from 29 Lines from D49-2491 x Improved Pelican and 32 Lines from D49-2491 x (D49-2491 x Improved Pelican).

Varieties or lines	Yield, Bu./A	Height in inches
D49-2491	17.6	19
Improved Pelican	19.0	59
Jackson	32.7	38
Ave. of breeding lines	29.0	39.4
Lowest yielding line	21.5	42
Highest yielding line	40.1	40
LSD .05	8.4	

TABLE 3.—COMBINED ANALYSIS OF VARIANCE FOR YIELD OF 24 LINES TESTED AT GAINESVILLE AND LIVE OAK IN 1957 AND 1958.

Source of variation	df	MS
Years	1	653.43**
Locations	1	1584.70**
Years x locations	1	1349.38**
Reps. within locations and years	4	228.26**
Varieties	23	83.54**
Varieties x years	23	37.48
Varieties x locations	23	149.43**
Varieties x locations x years	23	40.03
Pooled error	92	27.45

**Significant at .01.

processed soybean seed are almost equally divided between the oil obtained and the residue which is used as a high quality protein supplement in livestock rations. There are, at present, several oilseed crops grown in the United States which can supply the nation's demands for vegetable oils. Soybeans are probably unequaled at this time as an economic source of vegetable protein. If the population increase is as rapid as all predictions indicate and eating habits do not change, vegetable protein is likely to be in short supply in the future unless there is an increase in the potential supply. Leading soybean varieties now have a protein content of approximately 40 percent on a dry weight basis. A few old varieties and plant introductions have 46 to 48 percent protein but are very low in yield. Much of the future work will be directed toward obtaining a higher yield of protein per acre with as little reduction as possible in oil.

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Peanut Breeding in Florida

W. A. Carver[1]

Plant improvement by variety hybridization and pedigreed selection among and within hybrid lines was begun at the Florida Station in 1928. Results from early breeding studies on peanuts were reported by Stokes and Hull (4) and by Hull (3). Breeding by hybridization was started after yield trials with several selected lines of Spanish peanuts showed that they were not significantly more productive than commercial Spanish seed. It appeared then that the crossing of different peanut types would provide favorable combinations of characters and that from such a population lines of superior yield and seed quality might be selected. One of the first objectives of the peanut breeding project at the Florida Station was to produce a new variety type which would make a high yield of high quality peanuts free of concealed damage. This paper reports the progress that has been made in breeding new peanut varieties that possess these characters.

Experience gained in crossing peanuts up to the present time in Florida has revealed wide differences among parents in their ability to transmit desired characters. The first crosses made were between different varieties, of which the best parents were found to be white Spanish and Virginia jumbo runner. The varieties which have made poor parents because of low seed yields, poor plant type, or poor seed quality in their progenies are Valencia, Tennessee red and white, North Carolina runner, Rasteiro and Nambyquarae. The latter two are very late, large seeded, runner types from Brazil which produce large hay yields but low amounts of seed. Varieties which have proved intermediate in value as parents are pearl Spanish, Georgia bunch, and Virginia bunch.

A majority of the crosses made in recent years have been between lines extracted from earlier crosses, or between an extracted line and a Virginia jumbo runner variety or a small white Spanish variety. Extracted lines have generally made better parents than the older varieties, because fewer off-type forms occur in their hybrid progenies. The highest yielding lines from crosses have been of runner plant type combined with prolific fruiting habit, and large seed have had a yield advantage over small seed. However, the highest quality seed have been small in size (about 45 grams per 100 seed).

The peanut varieties grown in Florida when the improvement work began were small white Spanish, Valencia, and common runner. Spanish peanuts were accepted by the edible trade for several confections, and the Valencia variety was used largely for eating in the shell. These two types were planted on about 20 percent of Florida's total acreage; common runners were planted on the balance. The latter type, known to the peanut trade as North Carolina runner, was grown largely for hog feed. Spanish was also sometimes planted for early hog feed. The seed of common runners under average curing conditions contain a high percent of damage or seed decay; much of this is of a concealed type and very objectionable because such damage cannot be removed in processing the seed.

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The low yield of Spanish peanuts compared to that from runners has discouraged farmers in the planting of Spanish.

The usual higher quality of small seed, when cured in Florida, compared to that of large seed appears to be associated with percent of moisture or the total amount of moisture held within the seed when it is harvested. The larger seed, containing more moisture, is exposed to the dangers of seed decay over a longer period of time. Peanuts practically always come out of the ground at harvest time in sound condition. Success in retaining high quality in the seed depends largely on the time period elapsed between harvest and drying down to seven percent moisture. The critical period for seed decay ranges, in terms of moisture content, between 35 percent and 15 percent moisture as reported by Wilson (5). Good quality in seed has been associated with a thick hard hull which protects the kernel against ground damage before harvest and in the curing windrow or stack after harvesting. A peanut hull which can resist disease and insect attack also appears to be an important requirement for high quality in the cured peanut. High quality seed can also result from a natural resistance to an organism which causes concealed damage inside the peanut kernel (5).

The yield of peanuts per acre in Florida has increased greatly during the last 30 years (Table 1). During the period 1930-1939 the average yield obtained by farmers was 558 pounds, but for the ten years 1948-1957 this figure was 892 pounds of nuts per acre—an increase of 60 percent. Although other factors have contributed to this increased yield, improved varieties, as shown in Tables 1 and 2, have contributed a good share.

A breeding strain of hybrid origin, Florida 231-51, showed its superiority in the variety test of 1940, producing 89 percent more peanuts per acre than common runner. It continued to produce well in variety tests and excelled common runner peanuts by 35 percent over the years 1940-1947 (Table 1). Seed of Florida 231-51 were increased during the following two years and released to farmers under the name Dixie Runner in 1943 (1). The yielding ability of Dixie Runner has declined during recent years, producing 19 percent more than common runner during the five-year period 1943-1947 and only nine percent more during the ten-year period from 1948-1957. The 1958 season was a favorable year for Dixie Runner, as Table 1 shows. The recent performance of Dixie Runner is recorded in Table 2. Seed are about the same in size as common runner—100 seed weighing 45 grams. Dixie Runner seed have proved to be of good flavor and practically free of concealed damage. The latter quality of seed has allowed Dixie Runner to enter the edible trade. Previously, runner seed grown in the Southeast has been largely barred from the edible trade because of their high percentage of concealed damage. The popularity of Dixie Runner has continued strong in recent years despite its lower yield when compared to some new varieties. A more careful study of the Dixie Runner plant and a different field management might lead to a higher production from this variety. Dixie Runner appears to be a poor land peanut, since it has never produced well in comparison with common runner on fertile soil. When grown on fertile soil, hay yields increase and peanut yields become lower. Dixie Runner plants are vigorous growers with long branching vines and dark green leaves which are relatively free of leaf spot disease. When plants have set a crop of nuts, their leaves generally do not show the signs of fruiting maturity, but remain green. This characteristic of Dixie Runner can and often does cause delayed

TABLE 1.—PEANUT YIELDS IN FLORIDA

Year	Variety Test Yields on Experiment Station Farms			State Yield All Types Lbs/Acre
	Common Runner Lbs/Acre	In Percent of Common Runner		
		Dixie Runner	Early Runner	
1930-1939	—	—	—	588
1940-1947	941	135	—	647
1943-1947	1,040	119	130	622
1948-1957	1,830	109	130	892
1958	1,435	118	145	—

harvest, and results in a great loss of pods from the plants when they are dug. In areas where peanuts are an important cash crop and where the soil is average or below average in fertility, Dixie Runner continues to make a very satisfactory yield of peanuts.

A second superior line appeared in the variety tests in 1943, Florida 231-118, which was named Early Runner and released to farmers in 1951 (2). Tables 1 and 2 show the origin, yield, and seed qualities of Early Runner. Early Runner was released because of its earliness—maturing about ten days sooner than Dixie Runner. The hull of Early Runner is thin and may be subject to ground damage under some conditions. It produces a small vine of soft texture, has a prolific fruiting habit, and sets its pegs over a shorter period than Dixie Runner. If Early Runner is dug at the correct time, loss of pods in the ground is very small. The Early Runner variety is gaining popularity because of its high yield and good seed quality under most conditions. Dixie Runner pods and vines are damaged less when curing conditions are poor, as during prolonged rainy spells when harvested vines are in the windrow. The small soft textured plants

TABLE 2.—PEANUT YIELD AND QUALITY COMPARISONS. DATA TAKEN FROM FLORIDA STATION VARIETY TESTS.

Variety or Strain	Origin or Parents	Yield Sound and Mature Seed. Average 1954-1957		Total Seed Damage Percent, Average 1954-1958	Grams per 100 Seed
		Lbs/Acre	Percent		
Dixie Runner Fla. 231-51	Spanish x Dixie Giant (Jumbo Runner)	1847	98	1.20	45
Early Runner Fla. 230-118	Same	2343	124	1.30	55
Common Runner	Commercial Variety	1882	100	4.03	45
N.C. 2 (Jumbo Bunch)	Ga. 207-2 x White's Jumbo Runner	2140	118	7.94	92

of Early Runner make it much easier to handle with a combine than Dixie Runner.

The variety N. C. 2, a jumbo bunch type, was bred and released by the North Carolina Station. It ranked second in yield in the Florida variety tests during the seasons 1954-1957 (Table 2). The seed of N. C. 2 are about double the size of the Florida varieties. However, the percent of damaged seed was six times as large as in Dixie and Early Runner.

In experiment station tests, all peanut varieties were cured in field stacks covered with tar paper caps. When mechanical methods of harvesting and curing are used, the seed quality reaction is somewhat different from that of stack curing. Seed damage is generally much lower when mechanically cured. However, the seed quality ranking of the varieties would not be expected to differ very much from that shown under the stacking method.

It is estimated that 75 percent of the peanut acreage in Florida and in areas of Alabama and Georgia adjacent to Florida are planted to the Florida-bred varieties Dixie Runner and Early Runner. These varieties, especially Dixie Runner, have been invaluable to farmers and to the peanut industry in the lower Southeast. The high seed quality and good flavor of these two varieties have enabled the peanut trade, for the first time, to sell large amounts of runner seed to processors for manufacture into high grade confections.

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Lupines For Forage Production[1]

J. R. Edwardson and M. K. Corbett[2]

Forage lupines occupy the unique position of being the only crop developed for agricultural purposes during the 20th century. That the ancients cultivated lupines for different purposes is evident in the poetry of Virgil (70-19 B.C.) (14) and in the writing of Cato (234-149 B.C.) and Varro (116-28 B.C.) (38). These Romans describe planting and harvesting operations as well as turning under lupines for green manure. While there is a passage in Varro's work *De Agricultura* (Book 2) indicating that oxen might pasture on lupines, other ancient authors are explicit in statements concerning the unpalatibility of lupines: Theophrastus (370-285 B.C.) (39) states that lupines were not eaten green by any animal; Columella (21 A.D.) (1) recommends the use of lupine seed for cattle feed and for human consumption but only after boiling the seed in water (to remove the alkaloids); and Pliny (23-79 A.D.) (4) says that lupines are free from attacks by all animals (excluding insects) because of their bitter taste. De Candolle (12) states that *Lupinus albus* L., the white lupine, has been cultivated for at least 2000 years and that *L. termis* Forsk., a race of *L. albus*, has been cultivated for approximately 4000 years. These are the species referred to by the ancient Greek and Roman writers. The forage lupines developed in this country are the products of selections from *L. luteus* L., the yellow lupine, and *L. angustifolius* L., the blue lupine.

The two men chiefly responsible for the existence of forage lupines are E. Baur and R. von Sengbusch. In 1927 Baur in a lecture on plant breeding stated,

> ". . . that quite certainly alkaloid-free lupine plants will occur in the field completely by chance through mutation (hereditary variation), however since these solitary plants will certainly be heavily attacked by vermin they would generally be destroyed before flowering. It is of real importance that one work out a method with which it is possible to examine large quantities of young lupine plants for alkaloid content in order to find ultimately a sweet plant. Everything else then proceeds automatically."[3]

A field testing technique for the detection of alkaloids was developed by von Sengbusch in 1927 and by 1928 he had found three "alkaloid-free" *L. luteus* plants. Between 1928 and 1931 he also found "alkaloid-free" strains of *L. angustifolius*, *L. albus*, *L. perennis* L., and *L. mutabilis* Sweet (81). Other workers in different parts of the world using similar techniques later found other sources of "alkaloid-free" lupines.

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[3]Translated from "Die Süsslupine" (Page 12), by J. Hackbarth and B. Husfeld, 1939. Paul Parey, Berlin, 89 pgs. (32).

DISTRIBUTION

The genus Lupinus contains about 300 species (3). The center of origin of the Old World species is generally considered to be in the Mediterranean and Near Eastern areas (12, 76); the New World centers in Western North America, Central America, and the Andean region of South America (Ecuador, Peru, Bolivia) (34, 43, 76). None of the lupine species native to North America are of commercial importance. In 1948 Ritchey (62) reported on the value of sweet selections of blue, white, and yellow lupines for winter forage and seed crops in the southeastern United States. At present all forage and green manure varieties of lupines used in the southeastern United States are introductions or selections from introductions.

Derivatives of von Sengbusch's sweet lupine selections have spread the yellow and blue lupine species far beyond their original center of origin. At present, sweet varieties of *L. luteus* and or *L. angustifolius* are grown commercially for forage and seed production in East and West Germany, Poland, U.S.S.R., Hungary, Holland, France, Denmark, Sweden, Finland, Portugal, Italy, Union of South Africa, southeastern U.S., and New Zealand. The culture of forage lupines will undoubtedly occupy additional areas as research on adaptability and breeding continues in Austria, England, Greece, Algeria, Brazil, Argentina, Chile, Australia, and Japan (27, 30, 31, 75).

BIOLOGY

Crossability.—Both natural and artificial pollinations are controlled by flower structure. Lupine flowers contain 5 large oblong anthers and 5 small globular anthers. The filaments bearing the oblong anthers elongate first and the pollen matures and is discharged when these large anthers reach the level of the stigma. After the standard opens, the globular anthers are pushed upward by filament elongation forcing the pollen from the large anthers onto the stigma. While self pollination is the rule in both yellow and blue lupines, cross pollination by insects is known to occur in yellow lupine. Reported percentages of crossing vary from 1.3 to 40 in yellows; crossing occurs only rarely in blue lupines, reported percentages vary from 0 to 4.6 (21, 36, 37, 82). In Russia seed set has been reported to be 48.5 percent in yellow lupines, and 42.6 percent in blue lupines (the maximum 100 percent would occur if every flower in the raceme produced a mature pod). The upper flowers drop from the racemes even under favorable environmental conditions. Varying environmental conditions which drastically influence the percentage of seed set will be discussed later.

In Florida approximately 10 percent of the attempted intraspecific crosses produce seed in *L. luteus*, about 8 percent in *L. angustifolius*. In Germany an average of 63 percent of *L. luteus* intraspecific crosses and 4 percent of *L. angustifolius* intraspecific crosses are reported successful (36). While intraspecific crosses are made with relative ease in lupines, quite the reverse is usually true for interspecific crosses.

The chromosome numbers in the genus Lupinus are extremely variable with n numbers ranging from 16 the 26. Among New World species the most commonly occurring number is $n = 24$, however no regularity in chromosome number is apparent among Old World species (11).

Unsuccessful attempts to obtain interspecific hybrids between Old and New World species have been reported by Gollmick (22) and Bragdo (5). Bragdo obtained F_1 seed from the cross Old World *L. luteus* (2n = 52) x New World *L. polyphyllus Lindl.* (2n = 48). However, the seed failed to germinate. On the other hand, Fedetov (16, 17) reports successful crosses between the New World *L. mutabilis* (2n = 48) and Old World *L. varius* L., the only Old World species known to have 48 somatic chromosomes. There are several reports of viable crosses between New World species (5, 16, 17, 60); these for the most part involve species of little or no economic importance (60) or ornamentals (5). However, Fedetov (16) reports successful crossing of *L. mutabilis* with *L. pubsecens Benth.* Selections within the offspring of this cross are reported to contain the high oil content of *L. mutabilis* and to be earlier than *L. mutabilis.*

Early attempts to produce interspecific crosses between Old World species were unsuccessful (20, 63). Gollmick (22) did obtain some F_1 seed containing embryos from crosses between *L. angustifolius* and other Old World species, however these seed failed to germinate. A very interesting cross is that reported by Fedetov in 1946 (17) between *L. luteus* (2n = 52) and *L. angustifolius* (2n = 40). He obtained viable seed from this cross which produced completely sterile F_1 plants. Some of Fedetov's crosses involved commercially valuable species, and selection for recombinations in the offspring would be expected to produce new valuable commercial forms. No reports concerning production of new forms or attempts to overcome hybrid sterility have been found. Atabekova (2) in 1957 states that *L. angustifolius* and *L. linifolius* Roth. cross with ease. However, we do not consider *L. linifolius* to be a separate species but rather a variety of *L. angustifolius.* Recently Lamberts (53) has been able to obtain fertile offspring from the cross *L. luteus* x *L. Rothmaleri* Klink. Both of these species possess 52 somatic chromosomes (55).

Alkaloids.—It has been emphasized that the foundation of forage lupine culture has been the discovery of the so-called "non-alkaloid" or sweet strains of *L. luteus, L. angustifolius,* and to a lesser extent *L. albus.* The term non-alkaloid in reference to lupines is a misnomer since forage lupines do contain alkaloids, although in considerably lower concentrations than that found in non-forage bitter lupines. Since alkaloid concentration is so important in forage lupines, a brief discussion of lupine alkaloids seems pertinent.

"Lupine alkaloids" are found in a wide variety of plants which occur principally in the family Leguminosae, but certain of the lupine alkaloids also occur in the Berberidaceae, Chenopodiaceae, and Papaveraceae. Of the 50 lupine alkaloids listed by Leonard (54), 18 occur within the genus Lupinus, and the remaining 32 have been found in other genera of the Leguminoseae or in other families. Marion (69) and coworkers have examined the alkaloids of New World lupines in an extensive series of investigations. European workers have found the following alkaloids in the principal commercial species of lupine: *L. luteus* contains chiefly lupinine ($C_{10}H_{19}NO$), l-sparteine ($C_{15}H_{26}N_2$), and lesser amounts of lupanine ($C_{15}H_{24}N_2O$) and oxylupanine ($C_{15}H_{24}N_2O_2$); *L. angustifolius* contains chiefly lupanine accompanied by lesser amounts of oxylupanine, sparteine, and lupinine; in *L. albus* the principal alkaloid is lupanine with lesser amounts of oxylupanine and sparteine (65, 77, 78).

The alkaloid content of both sweet and bitter types of lupine is in-

fluenced by the environment. In general the alkaloid content of foliage and seed increases with decreasing levels of potassium (44, 45). The alkaloid content of *L. luteus* grown in light soils has been observed to be greater than the alkaloid content of the same variety grown in heavier soils: in *L. angustifolius* and *L. albus* the reverse was found (36).

Total alkaloids in seed are presented by Hackbarth and Troll (36). Bitter *L. luteus* seed contained 0.896 percent; sweet strain *8*, 0.049; sweet strain *80*, 0.013; and sweet strain *102*, 0.010 percent. The seed of bitter *L. angustifolius* was found to contain 1.079; sweet strain *411*, 0.49; and sweet strain *R 14*, 0.001 percent. Bitter *L. albus* seed contained 1.668; sweet Pflug's Gela, 0.16; and sweet Pflug's Ultra, 0.021 percent. The expression of each of these low alkaloid characters in the various sweet lupine strains is controlled by different recessive genes in the homozygous condition (28, 29, 33, 73). Klawitter and von Sengbusch (41) have proposed a method for obtaining completely alkaloid-free yellow lupines with a more refined alkaloid testing reagent. They also suggest crossing present low-alkaloid strains (i.e. *8*, *80*, and *102*) with selection in the progeny for double recessives.

In addition to the low-alkaloid lupine selections of the Germans, other workers have located low-alkaloid lines controlled by different genes: Ivanov (40) and Savvicev (64) in Russia have found yellow lupines with low alkaloid content and have incorporated this character into commercial varieties (64). Lamberts (52) in Holland has reported isolating a new type of low-alkaloid yellow lupine which is not controlled by genes found in the German lines. A low-alkaloid mutant has been recovered from the second generation of irradiated bitter blue lupine in Florida (15).

Forage Production.—The lupine species utilized for forage show marked differences in their rhythm of development. The majority of strains of yellow lupine, including Weiko II the most widely used yellow lupine in the southeastern United States, remain in the rosette stage about 5 weeks. Most blue lupine strains, including Borre the most widely used sweet blue lupine in this area, stay in the rosette stage about 3 weeks. Selections of spontaneous recessive mutations producing rapid early growth in yellow lupine (25, 26) have been incorporated into commercial lines. Weiko III sweet yellow lupine differs from Weiko II in possessing the genes for rapid early growth; Weiko III remains in the rosette for only 2 weeks (28, 74). At maturity there is little or no difference in height of Weiko II and Weiko III. Lamberts (51, 52) has found a dominant mutation for rapid early growth which has been incorporated into the sweet yellow lupine to form the varieties Palvo and Bipal. Varieties containing this dominant gene are taller than normal lines at maturity.

Rapid growth genes have also been found in *L. angustifolius* (35, 68). The Gülzower variety of sweet blue lupine contains a pair of homozygous recessive genes controlling rapid early growth. Varieties containing genes controlling rapid early growth not only provide earlier grazing than normal forms but also are better able to compete with weed growth during early development.

Forage production of low alkaloid blue and yellow lupine varieties is presented in Table 1 (dry matter) and 2 (green weight). In both Germany and the southeastern region of the United States there is a wide range of fluctuation in yields. The yields from the United States are based on three cuttings per year, while the number of cuttings in Ger-

TABLE 1.—COMPARISON OF FORAGE LUPINE DRY MATTER PRODUCTION IN GERMANY* AND SOUTHEASTERN UNITED STATES** IN POUNDS/ACRE.

Germany			United States				
Line	Years	Mean yield lbs./acre	Line	Years	G'ville Fla.	Quincy Fla.	Tifton Ga.
Weiko II	1950,51	4509	Weiko II	1951,56	2586	2271	2828
Weiko III	1950	3730	Weiko III	1956	4199	2138	3388
Sweet Blue	1950	3400	Borre	1951,56	2507	3858	4662

many is unknown. It is apparent that the yellow lupine produces more forage in the north-central area of Florida than does the blue lupine. However, the blue lupines are superior in forage production in northern Florida and Georgia. Extreme fluctuations in yield of both blue and yellow lupine occurred. In 1951, mean yields of dry matter for Borre and Weiko II at Gainesville were 783 and 994 pounds per acre, respectively; in 1954 yields were 3124 for Borre and 3974 for Weiko II. These yields were obtained from plots treated identically and possessing the same soil type. Unfavorable weather conditions, i.e. insufficient moisture and freezing temperatures particularly during early growth, and diseases are responsible for the greater part of this variation in yield. It is anticipated that fluctuations in yield will be reduced when disease resistant varieties become available.

Seed Production.—While weather and diseases greatly influence forage production in lupines, these factors exert a more extreme influence on seed production. Rainy weather following a hot dry period during seed harvest causes a loss of seed in both yellow and blue lupines. Seed loss under this condition is greater in blue lupine, whether they are low or high-alkaloid types, than in yellow lupine. Yellow lupine, Weiko II and Weiko III varieties, used in the United States possess the character "non shattering" pods.

Hackbarth and Troll (36) refer to a report by Konold in which it was

TABLE 2.—COMPARISON OF FORAGE LUPINE GREEN WEIGHT PRODUCTION IN GERMANY* AND SOUTHEASTERN UNITED STATES.***

Germany			Gainesville, Fla.		
Line	Years	Mean yield lbs./acre	Line	Years	Mean yield lbs./acre
Sweet Yellow	1948,53	24,603	Borre	1952,58	13,064
Sweet Blue	1948,53	21,903	Weiko II	1952,58	13,476
Sweet Yellow	1951,53	27,919	Weiko III	1956,58	14,241
Sweet Blue	1951,52	15,353			

*Data from Hackbarth, J. and Troll, H. J. 1956. Lupines als Körnerleguminosen und Futterpflanzen. Handbuch der Pflanzenzüchtung *4*: 1-51.

**Data from Annual Reports (1-6, 1950-1956) of the Uniform Winter Legume Tests of Varieties of Lupines, Vetches and Winter Field Peas. Summarized by Forage and Range Section, Field Crops Research Branch, Agricultural Research Service, Beltsville, Md.

***Data from Progress Reports, Project 612 "Improvement of Lupines by breeding for yield and insect and disease resistance." Fla. Ag. Exp. Sta.

found that pod-shattering varieties of yellow lupine lost 80 percent of their seed by shattering compared to non-shattering varieties. Zimmerman's (89) histological studies have shown that the sclerenchyma strand in the vascular bundles of the pod sutures is uninterrupted in non-shattering forms while this strand is broken in the center of the sutures of shattering forms. The non-shattering pod character is controlled by a recessive gene in the homozygous condition (24, 79, 80). The loss of seed through pod-shattering has been largely overcome in yellow lupine by incorporation of the genes controlling non-shattering into commercial varieties. Seed loss through pod abscission remains a problem in existing commercial yellow lupine varieties. However, recent reports form Poland (70, 71) and Holland (53) indicate that selections for non-abscising pods in yellow lupine have been successful.

In regions where moist atmospheric conditions are common during late stages of pod maturity, difficulties in obtaining seed of high germination are sometimes encountered in yellow lupine. This difficulty arises from the retention of moisture by hairy pods. This is not a problem in either blue or white lupines whose pods are glabrous. In yellow lupine Troll (72) found a spontaneous mutant characterized by pod hairs which broke away from the pod before maturity. Kress (47) observed a spontaneous mutation producing shortened pod-hairs and later found the same character in irradiated material (48); in both cases recessive genes control the character. A similar type of pod has been found by Lamberts (52). Recessive genes also control this pod hair character but whether the genes are allelic to those found by Kress is not known.

Another undesirable character for the culture of lupines is hard-seededness. Hard-seededness can lead to uneven stands and produce seed mixtures through volunteer plants. In wild forms this character is one of the factors responsible for perpetuation of the species. Von Sengbusch (81) showed that soft-seededness in yellow lupine is controlled by a single pair of recessive alleles. The soft-seeded character has been incorporated into the commercial yellow lupines grown in the United States. We are not familiar with any published report of the inheritance of soft-seedness in blue lupines, however, both forage and green manure varieties grown in the United States are soft-seeded. An interesting feature of *L. albus*, the white lupine, is the absence of wild characteristics. White lupines are soft-seeded, and possess non-shattering and non-abscising pods. The wild types of these characters have been lost while the culturally valuable characters have become fixed (probably through unconscious selection by man) during the 2000 or more years this species has been cultivated (36).

The non-shattering pod character has increased seed yield and the non-abcising pod character promises to further increase seed yields of yellow lupine in Europe. However, neither of these characters offers a solution to the problem of declining seed yields of yellow lupine in the southeastern United States.

Seed and forage production of sweet blue lupine in the southeastern United States has been impaired by man to a greater extent than by the remainder of the environment. Borre sweet blue lupine, developed in Sweden from the cross Swedish bitter x German sweet strain *411*, is well adapted to growing conditions in the United States. In the United States seed mixtures with bitter varieties have greatly reduced the value of Borre as a forage crop. It would be extremely difficult to eradicate the bitter contaminants from Borre by roguing because common bitter blue seed and

Borre seed are practically indistinguishable, and because they are bitter varieties (Florida No. 2) which have blue flowers, as does Borre.

The Blanco variety of sweet blue lupine, developed by I. Forbes Jr.[1] at the Georgia Coastal Plain Experiment Station, Tifton, has been designed specifically to obviate contamination with bitter varieties. The Blanco variety is equal to Borre in forage production in Georgia and Florida. This variety carries "marker" genes controlling white flowers and white seeds, and absence of anthocyanin in leaves and stems. It is anticipated that Borre will be replaced by Blanco as Blanco seed become available.

DISEASE AND INSECT PROBLEMS

Diseases caused by fungi, nematodes, and viruses are the greatest single problem confronting the grower of lupines in the southeastern United States. The lupine is afflicted from the time of seeding. In the seedling stage the plants may be attacked by the fungi *Rhizoctonia solani* Kuehn, *Sclerotium rolfsii* Sacc., *Fusarium* spp., or *Pythium* spp. These fungi in general attack the underground parts of the plant and cause damping-off of the seedlings. They are also capable of causing severe damage to the mature plant. If the plant survives the seedling stage, it is apt to be afflicted by the following fungi: *Glomerella cingulata* (Ston.) Spauld. and Schrenck., *Pleiochaeta setosa* (Kirchn.) Hughes, *Botrytis cinerea* Fr., *Sclerotinia sclerotiorum* (Lib.) D By., *Ascochyta gossypii* Syd., *Stemphylium solani* Weber, *S. botryosum* Wall., *Alternaria* sp. *Mycosphaerella* sp., *Phytophthora parasitica* Dast., and *Diplodia theobromae* (Pat.) Nowell. which manifest themselves mainly as leaf, stem, pod, or seed spots. Besides these disease spotting organisms, the mildews caused by the fungus *Erysiphe polygoni* DC., root knots caused by the nematode *Heterodera marioni* (Cornu) Goodey (*Meloidiogyne* spp.), and the mosaics caused by the viruses bean yellow mosaic and cucumber mosaic contribute to the difficulty in obtaining a profitable crop. All of these disease causing organisms have been isolated from infected lupines grown in the southeastern United States (10, 84, 85, 87). The amount and or extent of damage they cause is difficult to determine. From the standpoint of seed production in yellow lupine, it appears that the most important disease is that caused by bean yellow mosaic virus. Certainly this would not be true if the stand was drastically reduced by damping-off or root rotting organisms, or the plants defoliated by leaf spotting organisms. The virus disease over the past 10 years has contributed to the reduction of yellow lupines grown for seed production from 10,000 acres harvested in 1948 to 1,800 acres harvested in 1958 (U.S.D.A. Florida Crop and Livestock Reporting Service). The disease has received considerable attention since 1955 and a more detailed consideration of the virus diseases of lupines will be discussed here.

The first report of viruses causing a disease of lupines appears to be that of Merkel in 1929 (57). Since then virus diseases of lupines have been reported from many lupine growing areas of the world. Neill *et al* in 1934 (58) described a virus disease of blue lupines in New Zealand which they termed "sore-shin." The disease was later attributed to infection by pea mosaic virus (6). Kohler in 1937 (46) reported a virus

[1]Forbes, Jr. Blanco Blue Lupine. Press Release September 1959. Georgia Coastal Plain Experiment Station.

disease of lupines from Germany whose symptoms were not identical to those of "sore-shin." He termed the disease "lupine browning" and attributed it to infection by cucumber mosaic virus. Additional evidence concerning the identity of the virus and its alternate weed hosts was shown by Richter (61). In 1939 Chamberlain (7) reported the same disease from New Zealand. Pea mosaic virus was reported by Norris in 1943 (59) to be the causal agent of the "bunchy top" disease of *Lupinus varius* and the "sore-shin" disease of *L. angustifolius* in Australia. In South Africa, Klesser in 1953 (42) distinguished 5 virus diseases of lupines based upon symptom-expression. Two diseases of blue lupine were reported from Georgia by Weimer in 1950 (83). He considered both diseases to be epiphytotic. The virus he isolated from the Tifton area was both insect and mechanically transmissible. He suggested that the virus was possibly pea mosaic or a virus disease of peas. Weimer was not able to transmit the other disease, which occurred at Oglethorpe, Georgia. Decker in 1950 (13) reported a sap-transmissible disease of apparent virus origin in yellow lupine from several lupine growing areas in Florida. Ksiazek in 1957 (49) reviewed the virus diseases of lupines in light of world literature. Corbett in 1955 and 1958 (8, 10) reported that the most commonly occurring virus disease of blue, yellow, and white lupines in the southeastern United States was caused by strains of bean yellow mosaic virus. He considered the disease to be similar to the "sore-shin" disease of blue lupines and the mosaic disease of yellow lupines reported by Mastenbroek to be caused by lupinus virus 1 (56).

The symptoms of the disease were described in detail (8, 10) but will be briefly described here. Foliage of blue lupine plants at an early stage of infection develop a bronze color and tend to wilt. Some leaflets abscise and necrotic streaks develop on the stem. The necrosis is usually unilateral and the tip of the plant tends to bend to the necrotic side giving the appearance of a shepherd's crook. The disease usually is lethal.

The earliest visible symptom of infection in yellow lupine is a light vein clearing. The vein clearing becomes more pronounced and eventually develops into a chlorotic mottle. Various leaf deformations and abnormalities accompany the disease. The plants are stunted and the flower parts are abnormal. Abnormal flower structure does not permit normal pollination to occur; consequently the flowers abort leaving a naked raceme. Plants which are infected through seed transmission are very stunted and seldom produce any seed (10). Late season infection does not affect the pods which are already formed. Sometimes the main raceme will have a normal complement of seed pods, then the plant may become infected and the lateral racemes will not contain any flowers capable of supporting fertilization.

White lupines exhibit various leaf deformations accompanied by a very conspicuous chlorotic mottle. Very few white lupines are grown commercially in the United States, consequently information regarding seed production in relation to virus infection is lacking.

The disease at present is not of great importance to the production of blue lupines because the infected plant dies thus eliminating the within field source of the virus. This also eliminates the possibility of the infected plant producing seed which may carry the virus.

The disease drastically affects the seed yield of yellow lupines and has made their cultivation in the southeastern United States an unprofitable venture. With the accumulation of information concerning the virus it

seems plausible to attempt methods of control.

In theory, control of virus disease may be obtained through any one of the following practices: 1) control of the vector, 2) removal of the source, and 3) use of resistant varieties.

Attempts to control the vector of non-persistent aphid borne virus diseases by use of insecticides has met with little success because migrant flights of insects are impossible to control. Eradication or removal of the weed sources has been successful in some cases (86) but in general the host range of the virus is so diverse that removal of all alternate hosts would be impossible. Undoubtedly the use of specific weed killers will expand this type of virus control in the future with certain crops. This method of control has not been adequately investigated with lupines to warrant conclusions. At present, varieties of sweet yellow lupine resistant or immune to the virus are not available. Since control of the vector by conventional insecticide spray programs would not be economical and the degree of control doubtful, attempts were made to control the vectors by means of a barrier of immune plants (9). Simons (67) reported significantly less spread of potato Y when sunflower, an immune plant, was grown between the susceptible pepper and the virus weed source.

Corbett and Edwardson (9) reported from 1 year's data a significant reduction in number of virus infected plants and a highly significant increase in seed yields from plots of sweet yellow lupine which were surrounded by a 24 foot border of oats which are immune to the virus. At the initiation of this experiment all seed were virus-free. They pointed out that the experiments were to be continued over a period of 3 years to determine the feasibility of this method of control. After 1 year's exposure the seed from the protected and unprotected plots contained 0.94 and 2.2 percent virus, respectively. Plants grown from this seed the second year were nearly 100 percent virus infected at the end of the growing season. However, at 1 month before seed harvest the protected plots were only 26 percent infected as compared to 93 percent for the unprotected plots. The protected plots again yielded significantly more seed than the unprotected plots, illustrating that profitable seed yields may be obtained so long as the virus is detained until after the seed pods are set. The seed resulting from 2 years exposure in protected and unprotected plots tested 3 and 8 percent virus transmission, respectively. When this seed was planted for the third year exposure trial the plants in all plots were 100 percent virus infected after 4 months. There was no significant difference in seed yields. The use of protecting borders gave a profitable and satisfactory control of the virus for 2 years after which time the percent virus infected plants resulting from seed transmission was so high that the amount of infield inoculum and spread nullified the effect of the protecting border (unpublished data).

Although this method is a satisfactory stop gap measure it does not supply the ultimate in control. To obtain this the development of an acceptable sweet yellow lupine resistant or immune to the virus would be desirable. Since all lines or species of the genus Lupinus, except some perennials (8) proved susceptible to the virus the need for more diverse germ plasm was apparent. In attempts to obtain diverse germ plasm of the genus Lupinus letters were written to individual research workers in 66 countries. A total of 806 lines and species of the genus Lupinus were obtained from 52 countries. Of the 806 samples received 225 were lines of blue lupine, 290 were lines of yellow lupine, 68 were lines of white lu-

pine, and 223 were samples representing 54 species. Fifteen plants of all samples were tested in the greenhouse by mechanical inoculation with the lupine strain of bean yellow mosaic virus. Any plants which survived the first inoculation were reinoculated until they showed symptoms of the disease or were declared immune because the virus could not be recovered from the inoculated plants. All samples of the species *angustifolius*, *luteus* and *albus* were susceptible, reacting with symptoms similar to those described earlier. This indicates that very little if any variability for virus resistance exists in these species. The species of the genus Lupinus exhibited various symptoms to the virus. Some of the perennials were immune; and 2 samples, whose species category is yet unclassified, possessed a desirable reaction of hypersensitivity. In these 2 species the virus induces local lesions on the inoculated leaves and eventually goes systemic with tip necrosis. In both species the reaction is lethal. The same reaction prevailed when the plants were exposed to aphid transmission under field conditions (unpublished data). At present these 2 samples are the most promising sources of virus control in the development of a sweet yellow lupine possessing a hypersensitive reaction to the virus.

The remaining material is also being screened for resistance to the important fungal diseases, anthracnose and gray leaf spot (19, 88).

Cucumber mosaic virus has been isolated from blue lupines in Georgia but at present it does not appear to be a threat to lupine production (unpublished data).

Fortunately the insect pests of commercial lupines are not as numerous nor as destructive as the diseases. The most important insect attacking blue lupine in the southeastern United States is the lupine fly (*Hylemyia lupini* (Coq.) (23). The eggs are usually deposited in the terminal or lateral buds. The newly hatched larvae bore into the bud and cause a withering or death of the apex creating an opening for disease causing organisms. The larvae can easily be detected by the presence of brownish frass which covers the entrance of the burrow. When such a terminal portion of the plant is split open the larvae can frequently be found. The plant does not die but the affected branch will not produce seed. Kuitert and Guthrie (50) reported that an appreciable reduction in damage may be obtained through cultural practices. They recommend early planting and rotation with crops which require frequent cultivation, since tillage apparently destroys a large number of pupae. Although the fly may deposit eggs on plants of *L. luteus* the larvae will not survive (23).

The lesser cornstalk borer (*Elasmopalpus lignosellus* (Zeller) occasionally burrows into the stem of yellow lupine at soil level and the damage is sometimes confused with that caused by the lupine fly. Considerable damage may be caused by larvae of the corn earworm (*Heliothis zea* (Boddii) which burrow into the pods and damage the seeds. The presence of the insect is easily recognized by small holes in the pods and by the larvae within.

Another important insect pest of lupines especially sweet selections of blue lupines in Florida, is thrips. They are easily recognized at flowering time by simply shaking a raceme in the palm of the hand. They feed upon pollen and foliage and cause damage that sometimes is the limiting factor in seed production of sweet blue lupine in Florida. In Georgia the damage caused to the foliage by thrips (*Frankiniella tritici* (Fitch) and *F. bispinosa* (Morgan) has been used as a biological technique for screening blue lupine populations for low alkaloid plants (18).

Aphid species (*Myzus persicae* (Sulzer) and *Aphis medicaginis* Koch) besides being the vector of viruses have during some seasons caused considerable damage to lupines.

OUTLOOK

Further advances in forage lupine production will undoubtedly develop from combining disease and insect resistance characters with European varieties or their derivatives. In the past 32 years European workers have developed forage lupines from essentially wild species. An important impetus to these rapid advances has been the fortuitous control of agronomically valuable characters by single pairs of genes, most of which have been recessive. If this fortunate circumstance continues to hold (as it seems to, for resistance to anthracnose and gray leaf spot) for resistance to diseases and insects then the principal limiting factor to continued improvement will be the location of desirable genes. While irradiation has induced valuable mutations (short-haired pods and low alkaloid content), no new useable characters have been induced in lupines with this treatment. Selection within lines and species, which offers the most promising approach to improvement, is continuing.

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Tobacco Breeding In Florida During The Past Twenty Years[1]

C. E. DEAN[2]

The date when tobacco was first grown in Florida is not known. However, it was reported (5) that seed of Cuban tobacco were first introduced into the state about 1828. The first trial with Cuban tobacco as a commercial crop was started about 1830, and as a result, many farmers, particularly in Gadsden County, became interested in its production (15). This Cuban variety was largely replaced by another variety known as Florida Wrapper, which produced a higher yield of tobacco better suited to the manufacture of cigars. Several years after the Civil War, seed of a Sumatra variety were introduced, followed in 1884 by an introduction from Cuba which became very popular as a filler leaf (16). The Sumatra variety was grown almost exclusively until 1906, when a wrapper variety known as Big Cuba was developed from a cross between Sumatra and Cuban varieties. The Big Cuba variety almost entirely replaced the Sumatra variety in commercial production and continued in its position of prominence until about 1923. In 1921 a new wrapper variety, Round Tip, developed by the Connecticut Agricultural Experiment Station (6) was introduced and grown extensively in the state after 1923.

In 1923 the culture of bright or flue-cured tobacco was introduced into practically all of the northern counties of the state. Prior to this date, tobacco production was largely limited to Gadsden County and surrounding areas.

Tobacco research on an extensive basis was started in 1922 by the North Florida Experiment Station, Quincy, as a result of high crop losses with cigar wrapper tobacco caused by black shank (*Phytophthora parasitica* var. *nicotianae*). This led to the release in 1931 of a new black shank resistant wrapper variety known as Florida 301, which resulted from a cross between Big Cuba and Little Cuba varieties (17). This variety has provided the basic resistant germ plasm for practically all the black shank resistant varieties developed since that time. The wrapper variety Rg, developed from the progeny of a single surviving Connecticut Round Tip plant selected in a black shank infested field in 1929, was released about 1938 (9).

In 1926 a cooperative experiment was begun on flue-cured tobacco at the North Florida Experiment Station to determine the best varieties and proper fertility practices. However, no attempts were made to improve the existing varieties.

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FLUE-CURED TOBACCO BREEDING DURING THE PAST TWENTY YEARS

Flue-cured tobacco experiments were initiated in 1939 at the Main Station, Gainesville, as a result of a grant from the Florida Agricultural Research Institute.[3] The program was begun in an effort to secure and evaluate tobacco lines resistant to root-knot (*Meliodogyne* spp.), and to develop commercial varieties of flue-cured tobacco which combine high root-knot resistance with good leaf type and quality. Varieties grown in other areas were assembled and tested for resistance. In 1941 seventeen lots of seed were obtained from the North Florida Experiment Station, among which were six introduced selections from the United States Department of Agriculture described as having satisfactory resistance. Crosses were made between resistant lines and flue-cured varieties in an effort to combine acceptable resistance and quality. It was soon discovered that high levels of resistance were associated with small leaves, which resulted in low yields. An intensive program of crossing, backcrossing, and selection followed, utilizing the germ plasm available within *Nicotiana tabacum* found in the United States.

The need for other sources of root-knot resistance led to an evaluation of some of the *Nicotiana* species. As a result of root-knot screening tests, *N. repanda*, a species having its origin in southern Texas and northern Mexico (7), was found to have satisfactory resistance. Crosses were made in 1944 between *N. repanda* and several flue-cured lines, using *N. repanda* as the male parent. However, no hybrid plants were obtained. The only record of a successful interspecific cross between *N. tabacum* and *N. repanda* was reported by Kincaid (12). Seed of this hybrid between *N. repanda* and the cigar-wrapper variety Rg were obtained from the North Florida Experiment Station. These plants exhibited fair resistance in infested soil and were crossed with several selected flue-cured varieties.

Because of only limited success with the available root-knot resistant germ plasm, plant explorers from the United States Department of Agriculture were sent into Mexico, Central America, and South America to make collections of tobacco grown in these areas. Some 970 collections were evaluated, a few of which had some tolerance to root-knot. A total of 42 collections, mostly from Central America, had definite resistance to the root-knot nematode (4). As a result of intensive screenings of the introductions and crosses with flue-cured varieties, the line T. I. 706 was finally selected as a source of root-knot resistance within the cultivated species *N. tabacum*. In 1945 T. I. 706 was evaluated under Florida conditions and found to be a more promising source of resistance than *N. repanda*. Numerous crosses were made between T. I. 706 and flue-cured varieties, and from 1947 to 1950 an intensive screening program for root-knot resistance was conducted, with individual plant selections made on the basis of good resistance and acceptable flue-cured type. Most of the objectionable characteristics of T. I. 706 were eliminated and lines were obtained which produced a cured leaf of satisfactory quality. The only objection was that all lines with high root-knot resistance had small leaves which resulted in reduced yield. It soon became apparent that unless this association between high root-knot re-

[3]This statement and others following not covered in the Literature Cited were obtained from Experiment Station Annual Reports.

sistance and small leaves could be broken, the program would never be successful.

It was evident that this association was due to pleiotropism or to block inheritance and linkage (4) (19). If it was a pleiotropic response, the problem could not be solved. If linkage was involved, it was apparent that repeated backcrossing had not provided the solution. Some new approach was needed if success was to be achieved.

In 1950 a recurrent selection program was begun with 225 F_2, F_3, and F_5 lines having fair resistance and medium leaf type in an effort to recombine resistance and good leaf type into a commercial variety (19). This breeding plan was chosen on the assumption that the association was due to linkage and not pleiotropism. After three cycles of recurrent selection, plants were observed having good root-knot resistance and medium leaf width. However, the desirable flue-cured leaf type was not recovered. Genotypic correlations between leaf width and nematode resistance indicated that the association between the two was probably one of linkage and not pleiotropism (18).

About this time, a program was initiated designed to find lines which would combine to produce satisfactory resistance and leaf type in the F_1, and to determine whether heterosis might be important in the breeding program (19). Through the use of a male sterile line, the commercial production of F_1 seed could be possible. The desired combination of root-knot resistance and wide leaf type was unfortunately not obtained in the F_1. Other studies with first generation crosses between varieties of flue-cured tobacco indicated no over-dominance for yield and quality, and it was concluded that heterosis was unimportant in the progeny resulting from crosses using these varieties.

In 1955 two lines, Bel-I-30 and Bel-I-31, were obtained from the United States Department of Agriculture and tested for root-knot resistance. These lines resulted from a new approach to the problem of breaking the linkage between high resistance and small leaves. It was decided to cross root-knot resistant tobacco with the alloploid *N. sylvestris* x *N. tomentosiformis*. *N. sylvestris* and a member of the *Tomentosae* section are assumed to be the progenitors of cultivated tobacco (8). This original cross had been made in 1950, and in 1954 plants were selected having stabilized root-knot resistance and good flue-cured leaf type. Bel-I-30 was superior to Bel-I-31 in yield and quality; however, Bel-I-31 had higher resistance. Data on root-knot resistance and leaf size indicated that the linkage between resistance and small leaf size had at last been broken. Resistance was determined to be dominant and controlled by a single gene pair (4). It was also evident that the expression of resistance was subject to the effect of modifier genes, and that the modifier gene situation varied in different crosses.

In 1956, 31 Bel-F_3 lines were tested and found to have good resistance to root-knot. In addition, they had resistance to nematode root rot (*Pratylenchus* spp.), wild fire (*Pseudomonas tabaci* (W. and F) Stevens), and tobacco mosaic. Several selections had wide leaves and good flue-cured quality. In 1957, the number of selections from the two original lines had increased to over 100. These selections exceeded root-knot susceptible varieties in terms of yield and quality.

At the present time one line in particular seems to have very good root-knot resistance combined with leaf type and other elements of quality

currently demanded in a flue-cured variety. This line may be released as a new variety in the near future.

Although breeding and selecting for nematode resistance is the primary objective of the flue-cured tobacco breeding program, research is now underway to develop lines with multiple disease resistance. The diseases under consideration, in addition to nematode diseases, are black shank, Granville wilt (*Pseudomonas solanacearum* E. F. Smith), and Fusarium wilt (*Fusarium oxysporum* var. *nicotinae* Johnson). The flue-cured tobacco producing area of Florida is not troubled at the present time with the latter three diseases; however, there is no assurance that they will not become of importance in the future. Also, varieties developed in Florida might be planted in areas where these diseases cause heavy losses.

CIGAR-WRAPPER TOBACCO BREEDING DURING THE PAST TWENTY YEARS

Since its first appearance in southern Georgia and northern Florida in about 1915, black shank has developed into one of the most serious diseases affecting cigar-wrapper tobacco in Florida. Before 1940, the development of the black shank resistant varieties Florida 301 and Rg by the North Florida Experiment Station, Quincy, enabled farmers to produce tobacco of acceptable quality on soil heavily infested with the disease. Other diseases, including blue mold (*Peronospora tabacina* Adam), root-knot (*Meloidogyne* spp.), nematode root rot (*Pratylenchus*, spp.), and tobacco mosaic, made it necessary to enlarge the breeding program in an effort to develop varieties with multiple resistance.

In 1940 work on black shank resistance at the North Florida Experiment Station was concerned primarily with crosses involving the Rg variety and other lines having desirable characteristics. Selections from an Rg-White Honduras cross exhibited good resistance and slightly better leaf type than Rg. Several selections also combined some degree of root-knot resistance with resistance to black shank. Plants having resistance to tobacco mosaic obtained from an *N. digluta* x *N. tabacum* cross (11) were very similar to the wrapper parent Rg. *N. digluta* resulted from a spontaneously occurring amphiploid of F_1 *N. glutinosa* and *N. tabacum* (2).

Crosses between Rg and blue-mold resistant variety 57, obtained from the Division of Tobacco and Plant Nutrition, United States Department of Agriculture, showed promise of control of the disease under field conditions.

Each year the Rg variety was subjected to rigid selection to maintain and possibly improve resistance, yield, and quality and to supply seed for distribution to farmers. Selection revealed variation in leaf number and resistance to black shank, emphasizing the importance of continuous selection in the seed producing program.

Starting in 1940, attempts were made to produce interspecific hybrids between *N. tabacum* variety Rg and *N. debneyi*, *N. repanda*, and *N. plumbaginifolia* (12). These crosses were desired because the resistance to blue mold and black shank from *N. debneyi* and *N. plumbaginifolia* respectively (3) and to root-knot from *N. repanda*, would be valuable in cultivated tobacco varieties. First attempts were unsuccessful. However, through the use of mixed pollination as employed by Beasley (1) with cotton, seed set was obtained. As was mentioned before, this is the only record of a successful interspecific cross between *N. tabacum* and *N. repanda*. All

crosses produced fertile F_2 progeny and some selections within each segregating population had resistance contributed by the species.

In 1946 a flue-cured breeding line, RK 25, was received from the Division of Tobacco, Medicinal, and Special Crops, United States Department of Agriculture (13). RK 25 was developed from a cross involving T. I. 706 and White Stem Orinoco and backcrossed to No. 400. The fourth backcross had been completed in 1946, and the line had been selected for root-knot resistance by the North Carolina Agricultural Experiment Station. RK 25 was first grown at the North Florida Experiment Station in 1947 and was selected each year for resistance to black shank and root-knot as well as for desirable cigar-wrapper characteristics. Several lines were selected and in 1952 one of these was tested on a limited basis by growers. In 1953 the selection was released as Dixie Shade. This new variety has several advantages over the Rg variety, including more resistance to root-knot, larger leaf number and width, more body, and a higher yield potential. It also had black shank resistance equal to that of Rg. It rapidly became the most popular variety in the Georgia-Florida cigar-wrapper area and, at the present time, is grown more extensively than any other variety.

A cross of Rg with the variety White Honduras made in 1938 provided the origin of another cigar-wrapper variety. The line was backcrossed three times to Rg at intervals of three or more generations, with the third backcross made in 1946. This backcross was propagated by single-plant selections for the first four generations and by stocks of two or more plants for the last seven generations. The variety was released in 1958 under the name Magnolia (14). It has black shank resistance, yield and quality equal or superior to Rg or Dixie Shade, and is less susceptible to nematode root rot. Magnolia is grown on a limited basis at the present time, possibly because of its somewhat higher susceptibility to blue mold than Rg or Dixie Shade.

Blue mold may cause serious damage to tobacco under shades during certain seasons. Because of the importance of this disease, a large portion of the breeding program is being devoted to the development of new varieties with resistance. In 1955 several blue mold resistant lines obtained from the United States Department of Agriculture were tested and crosses were made between these lines and cigar-wrapper types. Several lines are showing combined resistance to blue mold and black shank. Material of interspecific origin recently obtained from Australia seems to have resistance to blue mold. This material originated from a cross between *N. tabacum* and the wild species *N. debneyi*, which has a high level of blue mold resistance.

Nematode root rot has been increasing in some tobacco shades during the past several years. Since resistance to root-knot is also accompanied by a degree of resistance to nematode root rot (4), flue-cured lines with root-knot resistance are being crossed with cigar-wrapper varieties in an attempt to develop a wrapper variety with resistance to both nematode diseases.

In 1955 seed of a cigar variety from the Dominican Republic were obtained from the Tobacco Section, United States Department of Agriculture. This variety, known as Licey, originated as a selection from a field of the cigar variety Quin Diaz and was reported to be resistant to black shank (10). Tests on black shank infested soil have shown Licey to be highly resistant, much more than Rg or Dixie Shade. It shows promise as being a new source of black shank resistance and is being crossed with Florida cigar-wrapper varieties and breeding lines. Another variety, Timor, which

originated in Java, was obtained from the Tobacco Section, United States Department of Agriculture, in 1957. This variety was also reported to have black shank resistance; however, tests on infested soil have shown the resistance to be low under Florida conditions, both from the standpoint of plant survival and root damage. It has subsequently been dropped from the breeding program.

The varieties Rg, Dixie Shade, and Magnolia are very similar with regard to leaf type, body, and other elements of quality. Grower preference for a variety with better handling properties and improved agronomic characteristics, together with new demands by the cigar trade, have placed new emphasis on plant type and leaf quality. Thus, it is desirable to change some of the qualities of the varieties now in production. The possibility of the use of reconstituted or homogenized tobacco as wrappers on lower priced cigars has made it imperative that the quality of Florida cigar-wrappers be improved so that they can successfully compete with those from other sections for use on the higher priced cigars. The variety Connecticut 49, which has some desirable elements of quality not found in Florida varieties, has been used in crosses with Rg, Dixie Shade, and several breeding lines. Selection is being made for quality factors contributed by the Connecticut 49 parent and black shank resistance contributed by the Florida varieties.

SUMMARY

Breeding programs involving both flue-cured and cigar-wrapper tobacco have been centered mainly around the development of disease resistant varieties, and since 1940 there has been a greater emphasis on the development of varieties with multiple resistance. Resistance to the root-knot nematode has been incorporated into flue-cured tobacco breeding lines, one of which may reach varietal status in the near future. Two new varieties of cigar-wrapper tobacco having resistance to black shank were released. Material of interspecific origin with resistance to blue mold is being used in the cigar-wrapper tobacco breeding program, and an introduced variety with superior black shank resistance may provide the germ plasm for better resistant varieties in the future.

Recently, the tobacco trade has become more exacting in its quality standards, making it necessary to place additional emphasis on quality in varietal development. Breeding programs are being modified where necessary to meet the changing demands of the grower and the tobacco trade.

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TWENTY YEARS OF PROGRESS IN PASTURE DEVELOPMENT IN FLORIDA

Economic Factors Infleuncing Pasture Development in Florida During The Past Twenty Years[1]

W. K. McPherson[2]

The economic situation Florida farmers have reacted to by improving more than 2.3 million acres of pasture since 1939, existed at least once before in American history.[3] Early in the Seventeenth Century the colonists found that the natural vegetation along the middle Atlantic coast of North America did not provide the amount and/or kind of forage plants needed to support an appreciable number of livestock.[4] The wild rye and broomstraw that grew naturally but not abundantly in the clearings along the streams were reasonably satisfactory forage plants. By the middle of the Seventeenth Century, these grasses were extensively supplemented with bluegrass and white clover, the seed of which was probably imported from England in the manure cleaned from the boats in which cattle were shipped. Nevertheless, during the next hundred years the scarcity of forage for livestock became so acute that marshlands were drained and meadows irrigated to produce forage for livestock in several of the middle Atlantic colonies.

When the land west of the Allegheny Mountains became accessible the supply of forage for livestock became more abundant. Here the land was more fertile and the plants that grew in the clearings along streams were more suitable for livestock feed. As settlement progressed westward, the supply of livestock forage became even more abundant because the soils were more fertile and grasses made up a large portion of the natural cover.

During that period the forage plants that would grow at little or no cost on land upon which it was not profitable to produce other crops provided an abundance of livestock feed. In fact, this supply of feed soon proved to be large enough to feed more forage-consuming animals than were needed to supply the demand of a rapidly growing human population for meat. As long as this was true, it was most profitable to produce forage-consuming livestock in the geographic locations where the natural combination of soil nutrients, moisture, and climatic conditions would support the growth of forage plants. In other words, the natural attributes of the land upon which other crops could not be grown more profitably determined the location of the forage-consuming enterprises with the locations in which the cost-price relationships were most favorably being developed first.

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[1]Florida Agricultural Experiment Station Journal Series, No. 1030.

[2]Agricultural Economist, Florida Agricultural Experiment Station, Gainesville, Fla.

[3]Preliminary estimates obtained in the Soil and Water Conservation Needs Study, currently being conducted by the United States Department of Agriculture, indicates there were 2,337,847 acres of improved pasture in Florida in 1958. The corresponding estimate for 1939 of 19,302 acres was made by the Agricultural Conservation Service, Fla. Bul. 108, State of Florida Department of Agriculture, Tallahassee, 1941.

[4]This account of the development of improved pastures from the Colonial period through the Nineteenth Century is largely based on "The Settlement of Grasslands" by Everett E. Edwards in *Grass*, Yearbook of Agriculture, Washington, D. C., 1948.

By the turn of the Twentieth Century the situation had begun to change. Practically all the land in the public domain upon which forage plants grew naturally had been homesteaded and the number of livestock being grazed on the publicly owned ranges was rapidly approaching the maximum number the natural forage would support. By making it possible to produce cattle on the southern ranges, the eradication of the cattle tick temporarily increased the supply of natural forage that could be used for beef production. Nevertheless, the situation became so acute by the late 1930's that droughts which would not have seriously affected the livestock industry a few decades earlier began to force the marketing of unusually large numbers of cattle; cattle that would not have been sold had the feed-stuffs needed to maintain them been available. When this happened ranchers began to realize that the only way the supply of forage-consuming livestock could be increased was to increase the production of forage grasses—i.e. hay and pasture.[5] By this time agricultural scientists had demonstrated the physical feasibility of increasing forage production by (1) planting improved varieties of forage plants, and (2) fertilizing and/or controlling the moisture content in the soil. Each of these methods call for increasing the amount of money expended to produce grass even though the cost of production is sometimes decreased on a per unit basis. Hence, any expansion in the amount of forage-consuming livestock produced in this country will take place as a result of farmers spending significant sums of money for seed, fertilizer, and the rights to use and the facilities for controlling water in the soil. To the extent these expenditures increase the per unit cost of production this type of change constitutes a transition from a decreasing to an increasing cost industry.

Farmers who expand production in increasing cost industries do so in the unique locations in which (1) no other enterprise will yield a higher return and (2) the difference between cost of production and selling price of that particular product is at a maximum. In some increasing cost industries production can be increased at the same locations in which smaller outputs were being produced at a lower cost. In the case of forage plants, however, this is not necessarily true. Increasing the output of forage plants calls for assembling the components of land, but there is no compelling reason to believe it will be economical to do this in the same locations in which forage plants grow naturally on the combination of land resources found there. Instead locations in which the output of the forage-consuming livestock can be expanded most economically will be determined by the cost of assembling the components of land. This does not mean that existing forage-consuming livestock enterprises will either move or go out of business. Instead, it only means that the farmers who increase their production by establishing new or expanding old forage-consuming livestock enterprises may not do so in the areas in which this type of animal is now being produced.

In the forage-consuming livestock industry, a very high percentage of the cost of production is incurred in acquiring title to or rights to use the components of land that will produce forage plants. Furthermore, variations in the cost of capital and labor needed to produce livestock at any given location are not large enough to influence the location of these

[5]Sometime in the future farmers may find that concentrated feed-stuffs are more economical sources of feed for cattle than forage. However, this possibility is not considered in this paper.

enterprises appreciably. Consequently, the location at which the forage-consuming livestock industries will be expanded will be determined by the availability and/or cost of (1) forage plants (2) plant nutrients (3) water (4) climate (excluding rainfall) and (5) space in locations in which other crops cannot be produced more profitably. The availability and mobility of each of these five components of land are examined in more detail in the following paragraphs.

Forage Plants. The role that plants play in the formulation and protection of soil has stimulated agronomists and plant physiologists to develop varieties that would grow under many climatic and moisture conditions in both this country and the entire world. Some work on grass improvement was initiated as early as 1890 and by 1900 several State Agricultural Experiment Stations had projects under way.[6] When World War II broke out the forage plants needed to make some improvement in the pastures outside the cash crop area had been developed. During the past 20 years plant breeders and agronomists have intensified their researches and have developed enough new varieties of grasses and legumes to make pasture improvement physically possible in most of the locations in which the cost of assembling the other component of land can be minimized.

Plant Nutrients. During the Nineteenth Century the supply of plant nutrients available for consumption by plants were essentially fixed components of land. As a result of the extensive work of soil scientists, the nutrients needed to support plant life can now be assembled at any given geographic location. In short, plant nutrients are now a mobile rather than a fixed component of land. The cost of making the several plant nutrients available at different locations depends upon (a) transportation costs and (b) the response of the soil to their application.

Florida farmers have no clear cut cost advantage that can be attributed to the low cost of transporting plant nutrients from their original locations. The fact that the potash deposits are located in New Mexico suggests transportation cost of transporting potassium to Florida might be higher than to other locations. On the other hand the extensive phosphate rock deposits in Florida suggest that this form of plant food should cost less here than in areas located farther away from the deposits. However, the location of the phosphatic rock deposits is not the only factor that determines the location at which phosphate plant foods are produced and hence are available at the lowest transportation costs. The cost of such things as power and sulphur at different locations may be equally or more important than the cost of transporting phosphate rock in determining where super phosphate can be produced most economically. Then too, there is some reason to believe that the variations in the cost of plant food that can be attributed to geographic location may be no greater, and perhaps considerably less, than differences in the cost of plant food that are attributable to size of the lot purchased.

In addition to the per unit cost of plant food, the responsiveness of the soil to the application of plant food is an item of cost in pasture improvement. The cost of applying plant food on soils that are responsive to treatment is less than the cost of applying fertilizer on the less responsive soils. In some locations the characteristics of the soil together with

[6]United States Department of Agriculture. Yearbook of Agriculture 1948, Washington, D. C. See especially pages 45 to 74 and pages 331 to 341.

the existence of a claypan that facilitates the control of the water table and hence reduces the rate of leaching making a combination of soil resources that is particularly suitable for the production of forage plants.

The making of plant food mobile coupled with the depletion of the supply of plant foods in the fertile soils have greatly reduced the importance of natural soil fertility as a factor influencing the location of agricultural enterprises. This is especially true in the long run and in the production of forage plants: plants that do not have a high enough value to be produced on the more favorable natural combinations of land resources.

In general it can be concluded that the making of plant nutrients a mobile component of land has been a major factor contributing to the improvement of pastures on land that had been considered sub-marginal prior to World War II. Although Florida farmers probably pay as much or more than farmers in other states for comparable amounts of plant food, the responsiveness of the soil to fertilizer and the economics of purchasing fertilizer in large lots (especially by large land owners) has no doubt contributed significantly to the improvement of pastures in the state during this period.

Water. The supply of water available to farmers is still a product of the natural environment and more particularly the hydrologic cycle. Hence, it must be concluded that the supply of water available for pasture improvement in particular geographic locations varies with the rainfall. From this it follows that the supply of water needed to increase the production of forage plants is more adequate in the humid and semi-humid areas than in the arid areas of the western range.

During the past 20 years considerable progress has been made in controlling the time and place farmers can use the water supplied by the hydrologic cycle in the form of rain. In addition to draining and irrigating land by techniques that were known well before World War II, farmers who have an ample supply of low cost water, either from lakes, reservoirs or aquifers, are controlling the level of the water table by using the same equipment to add and remove water from the soil. Thus, the technical developments in controlling water have contributed to increasing the productivity of pastures especially in the southeast and northwest parts of the country.

Whether or not it is economically feasible to control the water content of the soil to produce grass depends, of course, on the cost of doing it. This in turn varies widely from farm to farm and depends upon the cost of transporting it from either surface or sub-surface reservoirs and upon the amount that must be added or removed to maintain favorable growing conditions.

Climate (excluding rainfall). Scientists have developed numerous methods of controlling the temperature of and light in environments in which plants grow, but the cost of applying them are still so high that they are only used to produce plants with extremely high market values. As yet, the climate (excluding rainfall) in which practically all agricultural products are produced is a function of nature. Consequently, when the same combination of water and plant nutrients occur in different locations the greatest increases in forage production will take place in the areas in which the growing season is the longest providing of course, that suitable forage plants can be produced there.

Space. There is ample space in the United States to increase the volume of forage plants produced in the United States in locations not being used to produce more profitable crops. Of the 1.9 billion acres of land in continental United States (excluding Alaska) only about 465 million acres are used as cropland, 66 million acres of which are pastured. An additional 615 million of acres of land is occupied by forests, approximately half of which is grazed. After deducting 191 million acres used for special and miscellaneous purposes, there remains approximately 633 million acres of pasture and grazing land not used for other purposes.[7] Most of this land is located outside the area bounded by the Missouri and Ohio Rivers, commonly referred to as the bread basket of the nation. Clearly then, space is not a factor that seriously limits expansion of forage-consuming livestock production.

On the basis of availability and or cost of assembling the components of land into an environmental situation that will produce more forage plants than did the arrangements of these components of land that appeared in nature, it is possible to conclude that:

(1) A considerable amount of the increased production that will take place in forage crops, and hence, forage-consuming livestock, will take place in the humid areas of the nation, particularly in the south and southeastern parts of the nation where the growing season is relatively long, and

(2) Within these areas pasture development will take place most rapidly on the soils that are (a) most responsive to the application of plant foods, and (b) located in areas where the moisture content is favorable for plant growth or the water supply and topography are such that the water content of the soil can be controlled economically.

Some evidence supporting these conclusions is found in the locations in and the extent to which Florida farmers have improved pastures since 1940. During the 1940's, pastures were developed quite slowly. By 1949 less than 300,000 acres had been improved, but the rate at which new pastures were being planted was increasing rapidly.[8] In 1954, almost 800,000 acres of pastures representing about 75 percent of all the pastures that had been improved up to that time were reported as being fertilized (See Fig. 1). By 1959, 2,337,847 acres had been improved but there is no way of knowing how much pasture is now being fertilized until the 1959 census data are released (See Fig. 2).

The rise in cattle prices that followed World War II coupled with the relatively low price of space, climate and water in many locations stimulated the farmers in the state as a whole to improve pastures rapidly during the late 40's and early 1950's (See Fig. 3). During this period pasture development took place most rapidly in three areas i.e., South Florida in the vicinity of Hardee, De Soto, Highlands and Glades Counties, Central Florida and particularly Alachua and Marion Counties and in North Florida in the area of Gadsden and Leon Counties. The factors contributing to the differential rates of pasture improvement in these areas can be briefly summarized as follows:

South Florida. On the first upswing of the cattle price cycle following

[7]Hugh H. Wooton and James Anderson. "Major Uses of Land in the United States" Bul. 186 ARS USDA., Washington, January 1957.

[8]Soil Conservation Service cooperators had only improved a total of 260,586 acres by the end of 1949.

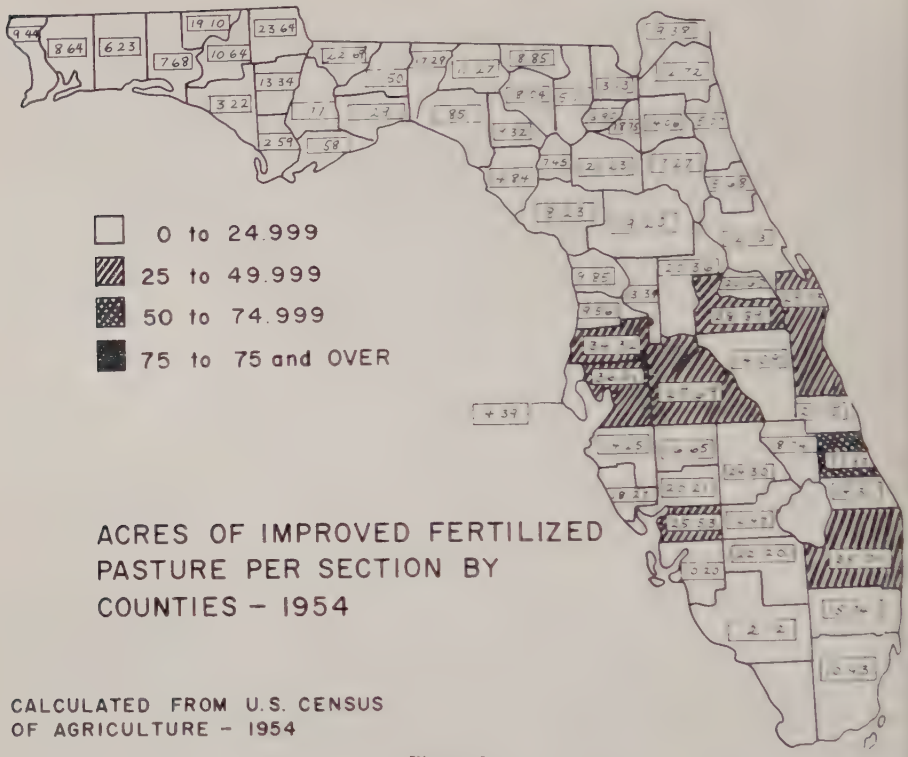
0 to 24.999
25 to 49.999
50 to 74.999
75 to 75 and OVER
ACRES OF IMPROVED FERTILIZED PASTURE PER SECTION BY COUNTIES – 1954
CALCULATED FROM U.S. CENSUS OF AGRICULTURE – 1954

Figure 1.

World War II ranchers in this area were able to increase their production of forage at a relatively low cost because, (1) varieties of pasture plants that were adapted to the climatic conditions prevailing there had been developed, (2) reliable information on the techniques for and rate of applying fertilizer was available, (3) space could be purchased at a price far enough below the capitalized value of the current earnings of improved pastures to make the investment profitable, (4) the water table was relatively high and the flat topography in much of this area made water control economically feasible in many locations and, (5) the cost of clearing the land and planting pastures was relatively low and in many instances watermelon or tomato producers were willing to bear most of the cost of clearing the land in return for short-term leases.

When cattle prices declined in 1952 and 1953 farmers in this part of the state reduced the rate at which they improved pastures. At that time they thought they were only making a short run adjustment in their beef cattle enterprises and expected to increase the rate at which they improved pastures when cattle prices begin to rise on the next cycle. However, when the cattle prices did begin to rise in 1956 and 1957, many changed their minds. By this time the price of much of the land in the area had risen far above the capitalized value of the annual income it was possible to earn by producing livestock. In many locations, the capitalized value of the discounted anticipated rate of future earnings exceeded the capitalized rate of current earnings by a very considerable margin. Con-

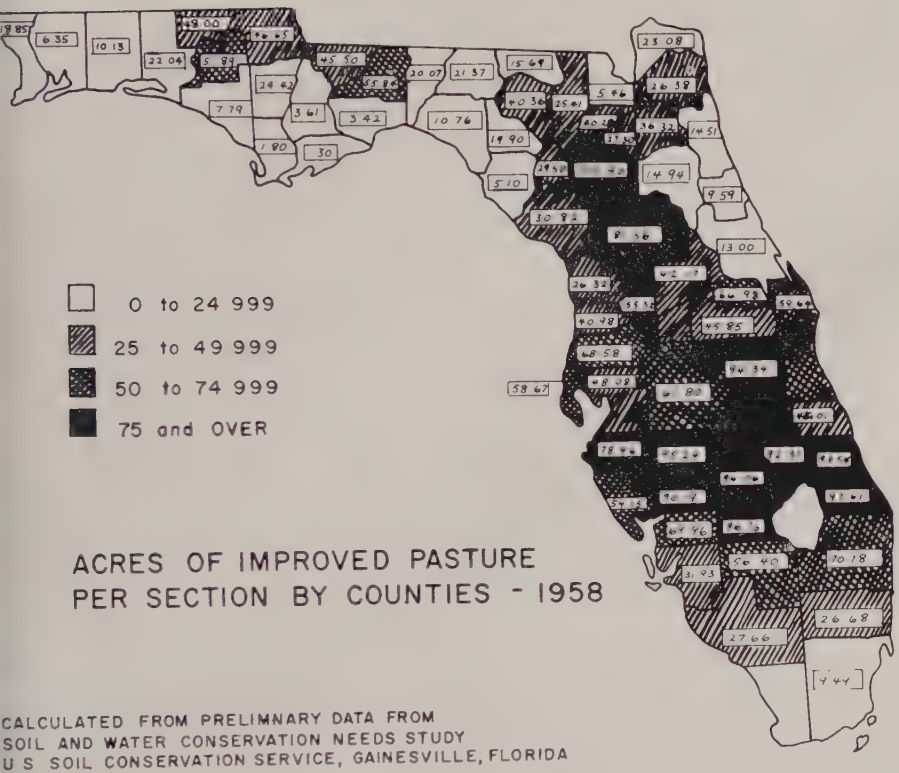
0 to 24 999
25 to 49 999
50 to 74 999
75 and OVER
ACRES OF IMPROVED PASTURE
PER SECTION BY COUNTIES - 1958
CALCULATED FROM PRELIMNARY DATA FROM
SOIL AND WATER CONSERVATION NEEDS STUDY
U S SOIL CONSERVATION SERVICE, GAINESVILLE, FLORIDA

Figure 2.

sequently, those who owned the land became more interested in the profits they could earn from the sale of land than from the profits they might earn from expanding their beef cattle enterprises.

North Florida. Farmers in this area increased the rate at which they improved pastures when cattle were rising in the late 40's and early 50's but for quite different reasons than did the farmers in South Florida. The decline in the profitability of raising cash crops in this area coupled with acreage restrictions on cotton and peanuts caused many farmers to convert cropland to pasture. In this respect they were extensifying rather than intensifying their farming operation. The cost of doing this was relatively low because the land had been cleared and the planting of improved pasture grasses involved little or no more cost than the planting of a cash crop (not including the cost of cultivating and harvesting).

North Florida farmers reacted to the 1952 decline in cattle prices rationally by reducing the rate at which they improved pastures. They too, expected to increase the rate of improving pastures again when the price of cattle rose, but like South Florida farmers, they also changed their minds. North Florida farmers did not increase the rate of improving pastures in the late 1950's primarily because (1) land prices were still rising (2) land that might have been converted to improved pastures was being placed in soil bank and (3) farmers were intensifying their live-

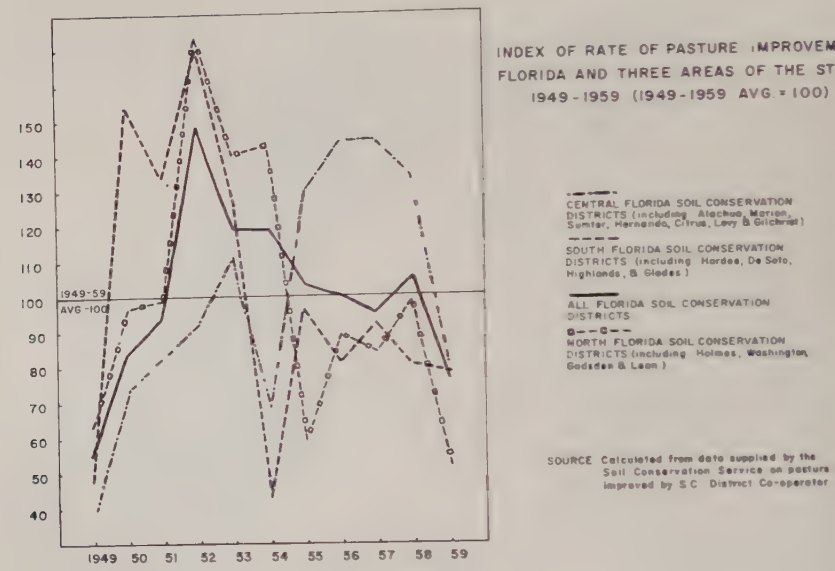
INDEX OF RATE OF PASTURE IMPROVEMENT IN FLORIDA AND THREE AREAS OF THE STATE 1949-1959 (1949-1959 AVG. = 100)
CENTRAL FLORIDA SOIL CONSERVATION DISTRICTS (including Alachua, Marion, Sumter, Hernando, Citrus, Levy & Gilchrist)
SOUTH FLORIDA SOIL CONSERVATION DISTRICTS (including Hardee, De Soto, Highlands, & Glades)
ALL FLORIDA SOIL CONSERVATION DISTRICTS
NORTH FLORIDA SOIL CONSERVATION DISTRICTS (including Holmes, Washington, Gadsden & Leon)
SOURCE Calculated from data supplied by the Soil Conservation Service on pasture improved by S.C. District Co-operator
150
140
130
120
110
100
90
80
70
60
50
40
1949-59 AVG.=100
1949 50 51 52 53 54 55 56 57 58 59

Figure 3.

stock enterprises by concentrating their efforts on producing feed grains and using them to produce fat cattle and hogs.

Central Florida. Central Florida farmers did not increase the rate at which they improved pastures as rapidly as did North and South Florida farmers during the first rise in the price of cattle following World War II. This was primarily due to the fact that, (1) the price of much of the land in Central Florida that was suitable for pasture development was as high or higher than comparable land in South Florida at that time, (2) the rolling topography of the area coupled with a low water table made the cost of controlling the moisture content of the soil considerably higher than in South Florida, and (3) the cost of clearing and preparing the land in this part of the state was relatively high—often from $50 to $100 per acre. Nevertheless, a start was made towards improving pastures in this part of the state prior to 1952.

When cattle prices began to rise about five years ago, Central Florida farmers reacted quite differently than North and South Florida farmers. In this area farmers increased the rate at which they improved pastures very substantially largely because, (1) the price of land did not begin to rise as soon as it did in South Florida, and (2) the value of improving pastures was more clearly established than it had been during the previous upswing in the cattle price cycle. By 1958, however, land prices finally did reach levels that approximated the level of land prices in South Florida and the rate of pasture improvement dropped off appreciably.

Future Trends. Although the rate of improving pastures dropped off sharply in the entire state, in 1958 many farmers were still investing substantial amounts of money in clearing land and in planting improved varieties of forage plants. Pasture improvement was progressing at this slower rate, (1) in the areas in which the cost of land plus the cost of im

proving it was still below the capitalized value of the annual income that could be earned by producing grass-fed cattle, and (2) on land that was owned by those who did not expect to sell it or use it for any other purpose for at least 15 or 20 years—a period of time long enough for them to amortize their investment and earn a reasonable profit on it.

Contrary to the predictions of many, rising land prices did not curtail the production of agricultural products in general or cattle in particular. Instead the production of agricultural products actually continued to rise, but this was the result of farmers endeavoring to minimize the cost of waiting until land prices rose still higher rather than as a long range source of income. They will continue to do this as long as the price of land continues to rise. In short, the boom in land prices has slowed down the rate of investment in pasture development in Florida and will do so at least until land prices become more stable.

If the value of land for some use that may be made of it in the future continues to exceed the current income capitalized at a reasonable rate over a long period many farmers will sell their land. Some of them will reserve the right to farm the land until it is actually used for some other purpose, i.e. they will lease the land back on a long-term basis. Others will endeavor to buy space at a price that when added to the cost of improving land will not exceed the value of the annual earning from capitalized farming. Owners of land that do not expect to develop it for non-agricultural purposes for a period of fifteen or more years may either invest in pasture improvements themselves or lease it for a long enough period of time to enable a lessee to improve it. Either owners or lessees will invest in land improvement if they can be assured the use of the land over a long enough period of time to amortize their investment and in addition earn a reasonable return on it.

Beef Cattle Improvement in Florida Over the Past 20 Years[1]

W. G. Kirk and F. M. Peacock[2]

Ponce de Leon brought the first cattle from Cuba to Florida in 1520, and Hernando de Soto landed a second consignment in Charlotte Harbor on May 25, 1539. Later introductions included animals from Spain and the Carribean Islands. These early importations, along with cattle brought in by the settlers, were the ancestors of the native stock which could be seen throughout Florida during the first four decades of the 20th century and were the foundation of the Florida commercial beef industry as it is known today.

Individual characteristics of most of the beef and dairy breeds of Britain and the Channel Islands could be observed in the native Florida stock. In some instances the red color could be traced to Devon bulls, typical set of horns to Ayrshire and the tan color to animals from Jersey Islands. Natural selection eliminated all animals which were unable to

[1]Florida Agricultural Experiment Station Journal Series, No. 1017.

[2]Vice-Director in Charge and Assistant Animal Husbandman, Range Cattle Experiment Station, Ona, Florida.

reproduce under the existing conditions of heat, humidity, poor feed and parasites. Cattle brought in by the early settlers usually succumbed to Texas fever within a few months; however, a bull might sire a few calves before becoming too seriously affected by the disease. Native cattle were small in size, most mature cows weighing less than 600 pounds. They matured slowly, lacked beef characteristics and on the available feed produced a calf only every two or three years. In the process of survival a hardy strain developed, immune even to Texas fever and adapted to the harsh conditions of Florida ranges.

Nutritional diseases took their toll with "salt sick" (lack of either iron, copper or cobalt) and phosphorus deficiency being prevalent on most Florida ranges. Becker *et al.*[3] stated in 1931 that "salt sick" caused the greatest loss to Florida cattle industry due to reduced calf crop, retarded growth and death of animals. Animals receiving insufficient phosphorus had low blood hemoglobin, fragile bones and were unthrifty, resulting in low production. These two nutritional diseases were corrected by supplying adequate amounts of bonemeal, common salt and "salt sick" mineral.

Operating expense was low because cattle were given little or no supervision by the owner, and any return from sale of meat or surplus stock was largely profit. There were few fences, and cattle roamed over extensive areas. In this way, they were able to obtain the minimum of feed which allowed the more hardy animals to survive even though production was extremely low.

In 1939, all of Florida except Collier County was declared free of Texas fever tick, and on September 14, 1944, the entire state was declared rid of this pest.[4] As areas in the state became free of the tick, pure bred bulls of the English beef breeds were brought in and crossed with the native cow. The offspring of this mating grew faster than the native calf, but since there was little, if any, improvement in feed conditions, the total results were disappointing. Offspring resulting from mating Brahman bulls and native cows were hardy, grew rapidly and at maturity were larger than the native animal.

Around 1934, screwworms were brought in with cattle coming from the drought areas of the southwest. This external parasite wrought havoc with new-born calves and injured animals, requiring increased supervision of the herds to prevent large losses.

From 1935 to 1940, progressive cattlemen, Agricultural Experiment Station and Extension personnel realized that without better feed conditions there would be little advancement in the beef cattle industry in Florida. Pasture improvement consisted of a minimum of land preparation, applying raw rock phosphate and seeding to carpet and common bahia grasses. Forage production increased and there was some betterment in the quality of feed, but scarcely enough to justify the expense. Cattlemen became aware that improved management practices with both pastures and cattle were needed if the Florida beef cattle industry was to be successful.

The average weight of cows kept entirely on central Florida native ranges in the present decade is estimated at 650 pounds. This increase

[3]Becker, R. B., W. M. Neal and A. L. Shealy. I. Salt sick, its cause and prevention. II. Mineral supplements for cattle. Fla. Agr. Exp. Sta. Bul. 231. 1931.

[4]Shealy, Arthur L. The beef cattle industry in Florida. Fla. Econ. Leaflet Vol. IV, No. 1. Dec. 1944.

in size is the result of the introduction of Brahman blood which gives a larger framed animal than that of the native cow of 25 years ago. Unless feed conditions are kept in step with improved breeding, the yearly performance of cattle kept on native range alone may not be much greater than in 1935.

The enactment by the Florida Legislature of the "no fence" law which makes the cattleman liable for damages caused many difficulties of adjustment but actually was a great boost to the industry. Cattle under fence could be given necessary attention, supplied adequate mineral mixture and separated according to class. Later, crossfencing of pastures permitted rotational grazing and keeping reserved areas for periods when feed was normally scarce.

The problem of screwworm control could be handled by herdsmen much more effectively with cattle in fenced pastures. The most recent advance in the livestock industry is elimination of screwworms. In 1959, through the combined efforts of state and federal agencies and Florida cattleman this pest was eradicated, resulting in an estimated annual saving of $10,000,000.00 to the industry.

What productivity level can be expected of cows kept under different pasture conditions? This question can be partially answered by referring to data obtained from three similar herds of 60 cows each kept at the Range Cattle Station in a three-year-period, 1955, 1956 and 1957. These cattle were well grown when placed in the various pastures at two years of age and are similar in quality to many cattle being raised on the better Florida pastures.

Herd number	1	2	3
Number of cows	60	60	60
Pasture per cow:			
Native	13.3	5.25	---
Improved	---	1.25	0.95
Pangola + clover, irrigated	---		0.30
Av. weight of cows, December	824	975	1134
Av. percent calf crop	62	81	82
Av. weaning weight, 7.5 mo. age	374	429	486
Av. grade calves, weaning	High Standard	Low Good	High Good
Av. yearly calf production per cow	230	348	397

The greater use of quality breeding stock has more than kept pace with improvement in quantity and quality of pasture forage. It has been estimated that in 1940 over 1,000 purebred beef-type bulls were brought into Florida. These animals, along with earlier and later importations, have had a tremendous effect on the quality of cattle in commercial herds. A large percentage of bulls used in Florida in 1959 were obtained from owners of purebred herds in the state. The breeds represented include Brahman, Hereford, Angus, Shorthorn, Santa Gertrudis and Charolais.

Offspring from native cows sired by Brahman bulls were superior to the original cow. One-half and three-quarter Brahman cows were excellent mothers and when mated to bulls of the other beef breeds, produced growthy, quality calves. Cattle on most commercial ranches in peninsular Florida have considerable Brahman breeding and varying amounts of one or more of the other beef breeds.

The best indication of the quality of beef animals being produced in Florida is the active market demand. Buyers are coming to Florida from other states in increasing numbers to purchase cattle to stock pastures and fill feed lots.

The development of feeds from waste products of the citrus and sugar industries has been a great benefit to all Florida cattle raisers. These energy feeds, along with ground snapped corn, provided the energy components of reasonable priced supplemental and fattening rations.

It has been shown by experimental trials and feed-lot operations that Florida steers can be fattened satisfactorily on pasture and in dry lot. Many cattle sold for slaughter grade U. S. Standard, with increasing numbers going into the Good and Choice grades each year.

The increase in the value of commercial cattle has been the greatest incentive for improvement in the industry. All classes of cattle have a much higher value in 1959 than 20 years earlier. For this reason alone it can be profitable to provide better forage and give the necessary management to obtain the largest returns.

Practices which have not been mentioned but have been valuable in the overall upgrading of beef cattle during the past 20 years include: culling of inferior and low-producing animals; a controlled breeding season; supplemental feeding when required to prevent excessive weight loss; inoculation against blackleg; control of external and internal parasites. As more of these and other practices are carried out in the herd, greater and more economical production will result.

Florida, as of January 1, 1959, was the 15th state in rank with 1,620,000 beef cattle. This is a 30 percent increase from the average number of beef cattle for the 10-year period beginning January 1, 1948. The yearly production of the Florida beef cow is below the national average due to: (1) a lower calf crop; (2) many animals being sold as vealers and (3) poorer feed conditions. Great advances have been made in total production and quality of beef marketed during the past 20 years, and there is every reason to believe that in the next two decades the beef cattle industry will continue to improve at as rapid a pace.

Pasture Development at the Range Cattle Station[1]

E. M. HODGES AND J. E. MCCALEB[2]

The ground had already been broken for pasture improvement in central Florida when research was begun at the Range Cattle Station in 1941. Ranchers were being encouraged by the federal Agricultural Adjustment Administration program to carry out certain practices on native land, including cutting twice with a heavy tandem disk, seeding carpetgrass or common bahiagrass and applying 1800 pounds per acre of finely ground raw rock phosphate. Thousands of acres of land prepared under this program yielded a two-fold benefit: first, higher per-acre forage production; and second, increased mineral content of herbage grown on sandy, peninsular soils. These improvement practices represented an important beginning and their greatest drawback lay in the failure to give any real help with winter feed shortage.

Forage trials were begun at the Range Cattle Station in November 1941 by R. E. Blaser of the Main Station. Interestingly enough, clover was the principal concern of these first plantings.

[1]Florida Agricultural Experiment Station Journal Series, No. 1047.

[2]Agronomist and Assistant Agronomist, Range Cattle Experiment Station, Ona, Florida.

GRAZING TRIALS

Pasture experiments initiated in 1942 were designed to evaluate common bahiagrass and carpetgrass under different fertilizer treatments. Steers grazed rotationally on paired five-acre areas during spring and summer produced beef gains per acre as reported in Table 1. The soluble fertilizer materials were applied annually in March at 30 pounds per acre of N, P_2O_5 and K_2O; rock phosphate and lime were applied at 1800 and 2000 pounds per acre, respectively, at intervals of three to four years.

TABLE 1.—BEEF PRODUCTION PER ACRE ON CARPETGRASS AND COMMON BAHIAGRASS

Grass Variety	Soil Treatment	No. of Years	Average Annual Gain Per Acre, Pounds
Common bahiagrass	None	5	20
Common bahiagrass	N-P-K-Ca	8	76
Carpetgrass	None	8	8
Carpetgrass	Rock phosphate	8	20
Carpetgrass	N-P-K-Ca	8	55
Carpetgrass	N-K-Ca, Rock phosphate	5	68
Carpetgrass	N-P-K-Ca, M.E.[1]	8	70

[1]Cu, Mn, Zn, Mg, Fe, Co, B.

Both carpetgrass and common bahiagrass were slow in becoming established and proved unproductive when planted without fertilization. Rock phosphate application slightly improved carpetgrass production during the first four years after treatment but added treatment failed to maintain the advantage. These and other comparisons in Table 1 lead to the conclusion that cattle gains were not enough to justify the cost and explain the shift to more productive grasses which took place as soon as they became available.

Pangolagrass, Pensacola bahiagrass and Coastal bermudagrass were planted in 1943, but required two years for establishment by the methods of culture then employed. The fertilizer treatment for all varieties through 1951 was 500 pounds per acre of a 6-6-6 mixture applied annually in March. This treatment became accepted as the standard for improved pastures over wide areas of Florida. Grazing through the spring and summer months by yearling and two-year-old steers produced the weight gains shown in the left-hand column of Table 2. Pangolagrass and Pensacola bahiagrass had been widely accepted by the time the early grazing trials spelled out their superiority. These results defined clearly the economic problem that led to rapid adoption of the more productive varieties for pasture improvement.

The grazing records of torpedograss and Coastal bermudagrass show them to be strictly second-rate in production. Over-aggressiveness of torpedograss and lack of vigor on the part of the bermudagrass further limit their value.

An accelerated fertilizer program was tested from 1952 to 1954, designed to show how the different grass varieties would be affected by an increased level of fertility. Applications of 300 pounds per acre of 9-6-6 all-chemical fertilizer were made in March, June and August, totaling 81, 54 and 54 pounds per acre annually of N, P_2O_5 and K_2O, respectively. Cattle gains obtained on seven grass varieties at the increased fertilization rate appear

TABLE 2.—ANNUAL BEEF PRODUCTION PER ACRE ON SEVERAL GRASSES AT TWO RATES OF FERTILIZATION.

Grass Variety	Average Animal Beef Gain per Acre, Pounds	
	1943-1951[1]	1952-1954[2]
Carpetgrass	70	165
Common bahiagrass	76	149
Pensacola bahiagrass	145	215
Pangolagrass	176	339
Coastal bermudagrass	130	199
Torpedograss	125	203
Argentine bahiagrass	—	215

[1]Pastures treated annually in March with 500 pounds per acre 6-6-6.
[2]Pastures treated in March, June and September with 300 pounds per acre increments of 9-6-6.

in the right-hand column of Table 2. No change in order of productivity occurred with the increased fertility level although pangolagrass outyielded Pensacola bahiagrass by a larger percentage than at the lower fertilizer rate. Carpetgrass and common bahiagrass responded strongly to the increased rate of treatment but still occupied an inferior position. Argentine bahiagrass proved to be similar to the Pensacola variety in productivity. There were no notable differences in either palatability or seasonal growth between these two varieties of bahiagrass.

A fertilizer rate trial on pangolagrass during 1955-1957 compared the grazing value of pastures receiving three rates of fertilization, including nitrogen at 90, 180 and 270 pounds per acre annually and enough P_2O_5 and K_2O to maintain a 2-1-1 ratio. Treatments were applied in six increments, extending from March through August, and beef gains per acre averaged 299, 483 and 595 pounds annually for the single, double and triple rates, respectively. Average daily gains made by steers in this trial were 1.23, 1.34 and 1.25 pounds per head, showing that the advantage of the higher fertilizer rates was entirely within the area of increased carrying capacity.

Temporary pastures have received limited attention since the emphasis has been placed largely on perennial grasses and their utilization. Fall plantings of oats, rye and ryegrass for pasture require extensive land preparation and heavy fertilization. Since they are subject to drouth damage and involve a heavy per-acre expense, these crops have been little-used for pasture in this area. Efforts to eliminate weedy grasses from improved pastures have indicated need for an intervening crop such as winter oats or rye. Grazing trials initiated to test the value of winter grains in a pasture renovation system have shown oats to be more productive than rye. Typical results were obtained in the 1958-59 grazing season when Floriland oats produced 254 pounds of beef gain per acre as compared to 166 pounds for Gator rye. Summer temporary crops such as sudangrass and pearlmillet have done poorly on flatwoods soils.

MINOR ELEMENTS

Carpetgrass planted in June and August 1942 and treated with a mixture of seven minor elements in addition to complete fertilizer and lime made a vigorous sod within three months. Ground cover and plant growth obtained in response to this treatment were equal to that made at the

end of a full year by carpetgrass lacking the minor element treatment. Grazing data from these pastures during the first five years of record showed the beef gains on the minor element treatment averaging 41 percent higher than those from carpetgrass not receiving minor elements. There was no consistent difference between the two treatments during the last four years of this trial.

Plot experiments with several minor element combinations on carpetgrass, common bahiagrass and pangolagrass showed all three varieties benefited from applications of copper sulfate while the effect of manganese and zinc sulfates was inconclusive. Bermudagrass has not responded to minor element treatment at the Range Cattle Station.

Minor element trials with legumes have been limited in extent; responses obtained have warranted recommendation of copper, zinc and manganese for all plantings on virgin land. Some boron has been applied to legume plantings although no boron deficiency has been observed in this area.

PASTURE LEGUMES

Lack of nitrogen in the sandy soils of the area makes the need for forage legumes an acute one. The greatest obstacle to legume production is the frequent occurrance of extremes of wet and dry weather. The first two years of planting winter clovers at the Range Cattle Station were complete failures. There followed two years of slight improvement and then two years that revealed the oustanding potential of Louisiana White clover-grass pastures. The two years of high production with clover were followed by a drouthy fall and winter that resulted in complete failure. This observation of drastic yearly changes in yield, apparently caused by lack of rainfall, led to establishment of an irrigation trial in January 1950. Non-irrigated clover was a complete failure in that year, while irrigated clover-grass pasture produced 492 pounds per acre beef gain. This and following years of record demonstrated the fact that white clover, with moisture control and orderly management, could be expected to live through the summer and provide grazing as early as December or January. Irrigated clover pasture is undergoing a steady acreage increase in central and south Florida, a development readily explainable on a basis of the high quality of forage produced during winter and spring months.

Summer legume improvement has been limited to hairy indigo. Used originally as a cover and green manure crop, hairy indigo has been proven to have genuine forage value. Mediocre palatability together with difficulty in obtaining reliable spring growth from natural reseeding have limited use of this legume by cattlemen. It seems likely that the modest cost of production combined with suitability for fall grazing and the residual effect of legume nitrogen on grass will encourage an increase in use of hairy indigo for pasture.

MANAGEMENT FACTORS

Need for more winter feed remains the greatest challenge to present-day herd and pasture management. Foremost among the methods developed for meeting this problem is the practice of reserving pasture for winter use. Protection from grazing from August to October, combined with suitable fertilization, has proved to be a reliable method of providing

grazing for November and later. Pangolagrass is best for this purpose but other pasture types may be used.

Extremes of wet and cold weather during the 1957-1959 period emphasized the importance of having stored forage available for winter feeding. The need for this safety factor becomes more acute as pasture improvement and cattle stocking rates are intensified. A number of workable hay and silage practices have been developed by research agencies and cattlemen, some suitable in one circumstance and some valuable in others. All involve a large measure of advance planning and their success depends upon meeting this requirement.

Rotational grazing has come to be widely employed in obtaining the full value of improved pasture forage. Cattle utilize available feed more completely when moved from pasture to pasture at regular intervals and even the short supplies available during the winter have more value when managed in this way.

The idea of rotation can be carried over from the handling of grazing cattle and applied to date of fertilization with equal benefit. Beginning with the fact that the greatest effect of fertilization of grass pasture comes within 30 to 60 days after application, it has been shown that treating different areas on successive dates will furnish a uniform supply of grazing. This practice has been used to avoid wasteful excesses of pasture and provide greater returns without increasing costs.

Pasture Development in the Everglades

R. J. ALLEN, JR. AND F. T. BOYD[1]

INTRODUCTION

The exceptional potential of the organic soils of the Everglades for forage and pasture production was recognized early in the development of the area, but cattle enterprises prior to 1939 were unsuccessful. The twenty-year period since that time has witnessed the successful introduction, expansion, and firm establishment of the cattle industry in the Everglades. As the original vegetation, which consisted almost entirely of custard apple and moon vine, willow and elder, or saw-grass sedge, offered no native range, the expansion in cattle numbers has been dependent on the development and increase in acreage of improved pastures. These improved pastures may indeed be considered the foundation of the Everglades livestock industry which depends almost entirely on grass-fed cattle.

This paper includes a brief discussion of the period dating from the establishment of the Everglades Experiment Station in 1924 through the year 1939, and a more detailed discussion of research results and other factors which influenced the establishment and rate of expansion of improved pasture acreage on the organic soils of the Everglades up to the present date, 1959.

[1]Assistant Agronomist, Everglades Experiment Station, Belle Glade, Florida and Associate Agronomist, Plantation Field Laboratory, Fort Lauderdale, Florida.

PRELIMINARY PERIOD 1924-1939

This period may be divided roughly into three sub-periods: (A) 1924 through 1930, a time of preliminary experiments with grasses and surveys of animal problems in the area; (B) 1931 through 1936, a time of reasonably satisfactory results in grass research but of discouragement with cattle; (C) 1937 through 1939, a time of further research on both forages and animals leading to better pastures and success with animals.

A. 1924-1930

Grass experiments were among the first projects to be started at the Everglades Experiment Station with plantings of fifty-one grasses and sixteen legumes. Difficulty was experienced in establishing and maintaining these plots due to fertility deficiencies and flooding, especially after the hurricanes of 1926 and 1928. However, during this period the need for copper was determined, drainage facilities were improved, and more than eighty different grasses were tested.

The first mention in the Florida Agricultural Experiment Station Annual Reports of animals in the Everglades area is in connection with a survey of cattle diseases made in 1925 and 1926. Almost universal sterility and what appeared to be malnutrition were evident in cattle grazed on the peat and muck soils.

B. 1931-1936

In 1931, active investigations of both pastures and livestock were begun. Pasture areas were treated with copper sulphate and planted to Dallisgrass (*Paspalum dilatatum*), centipedegrass (*Eremochloa ophiuroides*), carpetgrass (*Axonopus affinis*), and Paragrass (*Panicum purpurascens*). During the next 5 years the pasture acreage on the station was increased to 42 acres. It was found necessary to apply potash to maintain grass yields but phosphate applications gave little or no yield response. The pastures, primarily in Dallisgrass, were adequate during the spring and summer, but insufficient during the winter months. Temporary pastures were planted to ryegrass (*Lolium multiflorum*) and various small grain crops for winter grazing, and sugarcane was chopped for supplementary feed.

Problems with the station cattle during this period and failures with commercial herds in the area gave rise to the question of whether to continue with cattle experiments at the Everglades Station, or declare the muck and peat soils unsuitable for cattle production. However, workers at the station had observed that pastures fertilized with copper sulphate seemed to have some therapeutic value, and they believed that the problems could be solved.

C. 1937-1939

During the next few years chemical analyses of pasture grasses showed that phosphate contents could be adequate for plant growth but insufficient for animal health. Fertilizer recommendations were again changed to include phosphate and the minor elements Mn and Zn. New grazing trial pastures were established, palatability tests were conducted, and copper-molybdenum studies with both forages and animals were initiated.

The first results of the grazing trial were published in the annual report of 1939, and the first full year's results in 1940. St. Augustine (*Steno-*

taphrum secundatum) and Paragrass rated highest in weight gain per acre, even though the former rated low in palatibility tests. Centipedegrass and reed canarygrass (*Phalaris arundinacea*) failed to establish themselves due to weed competition; Dallisgrass failed during heavy summer rains; guineagrass (*Panicum maximum*) and molassesgrass (*Melinis minutiflora*) froze out; and carpetgrass, common Bahiagrass (*Paspalum notatum*) and Bermudagrass (*Cynodon dactylon*) had given low weight gains.

Water control investigations showed that water tables of 18 to 24 inches were best for pasture forage production, that sod forming grasses such as St. Augustinegrass were more satisfactory at higher water tables than the bunch grasses, and that high water tables reduced the rate of subsidence of organic soils. Such was the status of pasture research at the start of the period covering the past twenty years as mentioned above.

TWENTY YEAR PERIOD 1940 - 1959

The expansion of pasture acreage during these twenty years has been aided by further research, and has been more or less correlated with cattle prices, creation of local markets and ready outlets for slaughter cattle in the south Florida area, and progress on area-wide drainage and flood control. This period may be divided roughly into four sub-periods: (A) 1940 through 1947, a time during which important research results encouraged the expansion of pasture acreage on the organic soils; (B) 1948 through 1950, a time of recovery or replanting of pastures damaged or destroyed by the flood conditions of 1947; (C) 1951 through 1952, a time of very rapid and extensive expansion of pasture acreage coinciding with a steady increase in cattle prices, and improvement in marketing conditions; (D) 1954 to date, 1959, a time during which lower cattle prices slowed the increase in pasture acreage and tended to stabilize the Glades cattle industry, and during which flooding risk was reduced due to continued work on the Central and South Florida Flood Control Project.

A. 1940 - 1947

In 1941 it was reported that for the first time on record at the Station cows had lived on pasture on Everglades organic soils without supplementary feed of cottonseed meal for more than one year. These pastures had been top dressed with 100 pounds of copper sulphate per acre in addition to regular fertilization. During the next few years these results were repeated both with copper sulphate on the pastures and with copper and cobalt salts in the mineral mixtures. In experiments on a "no copper" pasture it was possible to produce familiar symptoms of emaciation, rough coat, and bleached hair color in only three months, and to restore the animals to normal with internal drenches of copper sulphate. The pacing gait and scours were shown to be more severe symptoms of the same cause, namely, copper deficiency, while weak calves and sterility appeared to be symptoms of a marginal copper deficiency.

Studies of the copper-molybdenum relationship showed that the same symptoms could be produced by feeding excess molybdenum. Surveys of forages grown on organic soils showed relatively high molybdenum contents. It was therefore recommended that mineral mixtures contain at least 5 pounds of copper sulphate per 100 pounds, and that pastures be given an initial application of at least 50 pounds of copper sulphate per acre and 15 pounds annually thereafter.

The pasture grasses tested in the grazing trials during this time were : Augustinegrass, pangolagrass (*Digitaria decumbens*), Paragrass, caribrass (*Eriochloa polystachya*), Coastal Bermudagrass, vaseygrass (*Paspam urvillei*), Dallisgrass, common and Pensacola Bahiagrass, carpetgrass, apiergrass (*Pennisetum purpureum*), Kraemer Island guineagrass, and alian ryegrass. By 1947, St. Augustinegrass had proved to be the most eliable of those tested and definitely superior in both carrying capacity nd weight gains. Other grasses recommended for the organic soils were angolagrass, caribgrass, and Paragrass. It was shown that overgrazing eriously reduced weight gains per acre, and that undergrazing, or allowng the grass to become too tall and mature, caused considerable loss by rampling and lower crude protein content. In planting pastures of the bove grasses vegetative material must be used and it was found that iscing in was as good or better than row planting.

The 1942 Annual Report contains the first mention of "Digit" or angolagrass. It also mentions the distribution of vegetative planting maerial of various grasses to ranchers in the south Florida area. For several ears it was the practice of the Experiment Station to supply small mounts, up to a pick-up truck load, of planting stock whenever it was vailable to anyone interested in setting out his own increase block. In his way these better grasses were rather quickly disseminated over a large rea, with pangolagrass predominating on the sand land pastures surounding the "Glades," and St. Augustinegrass being planted on most of he organic soil pastures.

By 1947, successful animal research had encouraged the planting of pproximately 14,000 acres to pasture on the organic soils, and at least ,000 acres on the adjacent sand land immediately west of Clewiston but ithin the present Everglades agricultural area. Most of this acreage as devoted to the growing of steers and stockers on grass, and it was aparent that the cattle industry could be successful in this area. However, uring that year there occurred the highest rainfall ever recorded in the rea, over 58 inches being recorded at the Station from June through October, and an estimated 75% to 80% of the Glades pasture land was nder water for two to four months. This was a serious set-back but did ot discourage the Glades cattlemen from continuing their operations as oon as they were able, and it helped to speed up the establishment of he Central and Southern Florida Flood Control District.

. 1948 - 1950

During the years following the 1947 flood some pastures were replanted o St. Augustinegrass, but many were allowed to come back to common Bermudagrass. A new problem was presented during this time by the evere outbreaks of photosensitization, or sunburn, during winter months. urveys and research on this problem showed that it occurred only on Bermudagrass pastures and was associated with the presence of a black nold on dead grass. It was possible to produce the condition experinentally and to prevent it by removing dead grass by mowing or burning. This was recommended, especially if a warm moist spell followed a frost.

A new grazing trial was established using 2-acre pastures of Roselawn nd common St. Augustinegrass, pangolagrass, Paragrass, caribgrass, and ommon Bermudagrass. The new location was on virgin Everglades peat nd was planned to indicate the weight gain potential and optimum carryng capacity of these grasses under average Everglades conditions. The

feeding of cottonseed meal was eliminated, but a relatively high level of copper was maintained in the mineral mixture.

Investigations of chemical weed control were initiated during this time and 2-4-D was found to be effective on most of the common broadleaf pasture weeds. Other investigations relating to pastures concerned a severe case of nitrate poisoning on ryegrass and a survey of the salt content of water from pasture wells in the area. Since high salt contents appeared to cut down mineral consumption and could thus indirectly cause copper deficiency, it was suggested that the salt content of drinking water be considered in making recommendations for supplementary minerals.

In 1949, the Central and Southern Florida Flood Control Project was authorized and work was started early in 1956. Also, in 1950, the Glades Livestock Market Association was established and weekly auction sales improved the marketing conditions in the area. These two events along with a demand for more steers and stockers than were available, caused more cattlemen to feel safe in developing more breeding herds of beef cattle, which of course created a need for more pasture acreage.

C. 1951 - 1953

This period was characterized by a steady rise in cattle prices, which, with the events mentioned above, encouraged considerable financial investment in pasture development. The pasture acreage was increased very rapidly from approximately 15,000 to 60,000 or 70,000 acres. Most of this increase was on virgin peat soils, but there was also a considerable acreage of vegetable land converted to pasture. There was also some 18,000 acres of sandy soils in the Clewiston-Moore Haven area planted to improved pasture.

As is often the case in such rapid expansion, mistakes were made and trouble occurred. St. Augustinegrass strains inferior to the Roselawn were planted on a few pastures, and some plantings were made of grasses not suited to Everglades conditions. In at least one instance, an extensive planting was lost by flooding because water control facilities were not installed first. Some pastures, especially on new peat land, were inadequately fertilized, especially in regard to copper, and many were grazed, or even overgrazed, before the grass had become really established. However, most of these difficulties were rather quickly corrected.

Work on the flood control project progressed during this period but had not reached the point where it could prevent flooding in the fall of 1953. A few ranches were flooded at that time but the area-wide conditions were not serious.

The Experiment Station grazing trial mentioned above was continued with Roselawn St. Augustine being equal or better in weight gains and highest in optimum carrying capacity. Common Bermudagrass was removed from the trials due to low production and was not recommended for pastures.

These trials also clearly showed the fluctuation in seasonal carrying capacity of pastures from summer to winter, and emphasized a need for leveling out the feed supply. Work on preserving excess summer grass as silage and storing and self-feeding it in the pastures was started. A sod seeding drill was obtained and experiments were started on interplanting winter grazing crops into established pastures.

Work with winter grasses and legumes was continued both in plots and under grazing, the principal difficulties being weed competition, and ful

stablishment coming too late in the winter season. Italian ryegrass and ats were the most reliable for winter pasture although there were occaonal cases of nitrate poisoning. However, it was possible to predict that his would probably occur immediately after a rain on pastures which had reviously been dry, and to remove animals until the danger had passed. lfalfa in combination with not over 5 pounds per acre of ryegrass, planted ith a grain drill, appeared to be the best legume-winter grass combination.

White clover (*Trifolium repens*) was planted on many of the new astures in the area and gave good late winter grazing for one or more easons, or until the permanent grass, usually St. Augustinegrass, became ell established and crowded it out. A few isolated plantings of other egumes were made, notably alfalfa (*Medicago sativa*), crimson clover *Trifolium incarnatum*), and Berseem or Egyptian clover (*Trifolium lexandrinum*), but results did not warrant repeat plantings.

The yellow sugarcane aphid (*Sipha flava*) and the greenbug (*Toxopera graminum*) became serious pests of pangolagrass and were also found o attack ryegrass in the young seedling stage. The entomologists were rought into the pasture research work and insect control experiments nowed parathion, malathion, and TEPP to be effective. Host plant surveys and seasonal population studies on these insects were initiated, along ith insecticide residue studies. The spittlebug (*Tomaspis bicineta*) was ound to be a potentially serious pest on pangolagrass and possibly on St. ugustinegrass.

. 1954 - 1959

At the beginning of this period cattle prices dropped sharply and the apid expansion in pasture acreage came to a virtual stand-still. There ere some changes in ownership, but already developed pasture land was bandoned in only a very few instances. Some ranchers have made conacts with sod dealers to augment their income and several sod growers ave moved into the area in recent years, planting their own fields to the itter Blue turf strain of St. Augustinegrass. At present it is estimated hat approximately 10,000 acres are, or have been, involved in this enterrise, either as pasture temporarily converted to sod, or as strictly sod fields hich in many cases are temporarily grazed.

The Flood Control Project is at present completed sufficiently to be ffective in preventing flooded conditions within the Everglades Agricultural Area. The perimeter dike is completed, the main canals through he area have been made wider and deeper, and 4 of the 5 pump stations esigned to remove 3 4 inch runoff per day from 810 square miles are in peration, and the fifth is about to be completed. These facilities have een very effective in handling the above average rainfall occurring during he summer and fall of 1959.

Results in the various fields of animal research work, in producing aster growing, higher grade, and healthier animals, has made the mainenance and management of high quality pasture more important than ver.

Fertilizer recommendations from the Experiment Station have been or the most part based on soil samples, and will generally be one of three ormulas at 250 to 500 pounds per acre. These formulas are 0-8-24 for new astures, changing to 0-10-20 or 0-12-16 after several years. Boron has been dded to the minor element recommendations.

It has been difficult to provide shade on Everglades pastures. Artificial

shade is impractical due to expense and the nature of the soil. Trees must be protected by fence when young, and many of them have been stripped of bark and killed by the cattle when large enough to have the fences removed. The most satisfactory to date have been the Australian Pine (*Casuarina lepidophloa*), and the clammy cherry (*Chordea alba*), which apparently have less palatable bark. The introduction of Brahman cattle has materially reduced the necessity for shade in the pastures.

The yellow sugarcane aphid and the greenbug have continued to be the most serious pasture insect pests. Pangolagrass pastures and seedling stands of ryegrass and oats are attacked for a short time in the fall, usually during November, and lesser concentrations occur on pangolagrass in early spring. These insects may be controlled by spraying, or if left alone, will eventually be checked biologically by fungus diseases or parasites. They have, however, caused a reduction in pangolagrass plantings in the Glades area.

The rhodesgrass scale (*Antonina graminis*), found principally on carib grass, has been checked biologically by the introduction and release of a parasitic insect.

Other insects, such as leafhoppers (family Cicadellidae) and spittlebug while apparently not serious pests, are under observation and study to determine what effect they may have on pasture production.

Weed control has proved to be an important item in pasture manage ment. The high nitrogen content of the organic soils produces rapid and prolific weed growth, especially in early spring, on pastures which have been frosted or overgrazed. Chemical control with 2-4-D, properly applied, has generally been more effective than mowing.

Several poisonous weeds occur on Everglades pastures but only butter weed, (*Senecio glabellus*), has become serious. Due to its light, windborne seed, it has become widely disseminated over the area and has caused some cattle losses. It cannot be killed by mowing and it is very difficult to prevent seed formation by this method, but it can be effectively controlled chemically.

The grazing trials started at the station in 1951 were continued for five years, when the work was summarized and the trials revised. St. Augustinegrass was again the best in weight gains and carrying capacity but was followed closely by Paragrass and caribgrass in spite of these being out of production an average of 13 days per year due to frost. Pangolagrass was injured by aphids in addition to frost, and also invaded by Bermuda grass. In the revision of this trial, caribgrass was discontinued due to slower recovery from frost. Pensacola and Argentine Bahiagrass were added and pangolagrass replanted.

These trials indicate that gains of up to 1000 pounds per acre can be made with yearling animals on average Everglades pastures. Close to 90 percent of this gain will probably be made from March through October with animals gaining up to one and one-half pounds per day on spring pasture but only one-half to two-thirds of a pound per day during the winter. Continuous grazing of St. Augustinegrass was equal to rotational grazing, and all pastures in the revised trial are being continuously grazed.

The Bahiagrasses have not equaled the other grasses in weight gain on yearling animals but have indicated a greater carrying capacity, es pecially during the winter months. The Argentine strain is about as frost resistant as St. Augustinegrass, while the Pensacola is more so. A consider able part of the pasture acreage developed or replanted in the Glades are

during recent years has gone into Bahiagrass, primarily for use as breeding herd pastures. The grazing trials have shown that Everglades pastures can furnish grazing for from three to four yearling animals per acre during late spring and summer, but that during the winter months the stocking rate may drop to less than one, and even to none after heavy frosts.

Grass silage investigations have been continued in an effort to compensate for this seasonal fluctuation in pasture production and to utilize that production more efficiently. Yield trials have shown that Glades pasture grasses are capable of producing 40 to 50 tons of green weight per acre from April through October. Satisfactory grass silage has been made from all the principle pasture grasses using molasses or sodium meta-bisulfite as a preservative. It can be stored in the pastures and self-fed during the winter period.

The principle objection to this practice has been the high percentage of spoilage which occurs in the temporary field stacks or bunkers. Recent work has shown that this loss can be materially reduced by the use of polyethylene or vinyl plastic covers.

Interplanting of winter annual crops such as ryegrass, oats, and various legumes, into established pasture sods has given varying results, depending largely on the method of planting, the condition of the pastures and the weather. Sod seeding drills have proved more effective than broadcasting especially if adequate fertilizer is used in the drills. Pasture grasses must be short enough to allow sufficient light to reach the seedlings, and the weather must be cool enough to keep the permanent grasses relatively dormant. Cattle should be kept off the interplanted pastures until the winter crops have become firmly established.

Silage and interplanting, as pasture supplements, have not yet been widely accepted by cattlemen in the area, but as techniques are developed which will insure more successful results, these practices should become more generally used.

Many cattlemen plant winter pastures on prepared ground, usually with ryegrass, and many supplement their regular pastures with molasses. In emergencies such as the exceptionally cold winter of 1957-58, hay and other feeds have been brought in from out of state, and in some cases vegetable by-products such as cull potatoes or celery strippings have been used for feed. Where it has been available, sugarcane has been a good supplement for winter pasture, either chopped or fed as whole canes. A project is at present underway at the station to select sugarcane varieties especially for winter forage use.

Preservation of excess summer grass by thermal dehydration has not been economically feasible due to high moisture contents of available forages. The development of a mechanical de-watering press to be used prior to dehydration, and the success reported from other areas with pelleted forages may change this picture and provide a local source of feed to supplement pastures.

It is felt however, that pastures will remain the basic factor in cattle production in the Everglades. There are at present over 90,000 acres of pasture on organic soils in the area and there are over 400,000 acres of undeveloped organic soils. At least three fourths of this will probably go into pasture land. In the not too distant future there should be from 800,000 to 1,000,000 head of beef cattle grazing on some 400,000 acres of well managed pasture in the Everglades Agricultural Area.

Pasture Herbage Changes in Florida During the Past Two Decades (1939-1959)[1]

GORDON B. KILLINGER[2]

Seventy-one years ago (1888) the Florida Experiment Station's first Director's first bulletin was released and was about grasses for Florida (12). Since early beginning some 15,000 plant introductions, largely grasses and legumes, have been screened by one or more investigators in the experiment station system. The primary purpose of screening or testing plant introductions has been to find, increase and release new species or strains of grasses or legumes superior to those already commonly grown. Plant breeders with the same objective in mind have added their share of new varieties.

A report on "Florida's Pasture and Forage Crops" by Killinger and Hull (10), published in an economic leaflet in 1953, outlines the more important changes in pasture species since 1910.

In 1953 McCloud (14) reported in the Soil Science Society of Florida Proceedings on "Forage and Cover Plant Introductions by the Florida Agricultural Experiment Station." He reported that 24 plants were released to Florida's farmers during the first 66 years of plant introduction. The early history of plant introductions as well as the dates of introduction, plant introduction numbers, botanical names and native home of proven forage and cover crops in Florida are listed. The time lapse between the date of plant introductions and the date of release to growers in the state varies from two years to over ten years for a single plant species.

Two decades ago or 1939 found Florida ranchers on the threshold of a new era so far as pasture plant species, improved forage composition, higher yields and more nearly year-round grazing were concerned.

The first comprehensive publication on clover for Florida pastures was in 1939 by Blaser (2) in bulletin 325, "Preliminary Pasture Clover Studies." Blaser stressed adapted clover varieties, time and rates of seeding, adapted soils, seed inoculation, lime and fertilizer requirements and tentative methods for grazing. Prior to 1939 there were only a few hundred acres of clover being grown with mixed success and no definite formula for its production. In the following years, particularly during the 1940's, white clover production increased to over one quarter million acres in the state and became an important factor in the successful cattle industry which followed.

Warner (19) in 1939 authored press bulletin 541 "Lupine, A Seed-Producing Winter Legume." This was the first publication on a legume which in a few years became a valuable grazing as well as soil-improving crop for Florida, particularly north and west Florida. Work up to and during 1939 was primarily with the Bitter Blue lupine species; however, this was followed by the release of Sweet Blue and Sweet Yellow varieties. This early pioneer work with the Bitter species laid the groundwork for successful lupine culture including the economic harvesting of seed for increase plantings. Plantings of lupines increased during the 1940's until

[1]Florida Agricultural Experiment Station Journal Series, No. 1018.
[2]Agronomist, Florida Agricultural Experiment Station.

over one-half million acres were being grown, with about 100,000 acres furnishing grazing. Later diseases, particularly a virus, cut down on the planting of lupines.

In 1940 Stokes (17) extolled the virtues of Alyce clover in an article printed in the "Southern Seedsmen." It was during the late 1930's that Alyce clover came to be a popular hay, grazing and cover crop. This summer legume was adapted to all of the Florida peninsula, and by 1940 over 100,000 acres were being grown in the state. Blaser and Ritchey (4) reported on Alyce clover as a "New Hay and Pasture Crop for the Southeast" at the Southern Agricultural Workers Meeting in 1941. Alyce clover added materially to the quality of forage, both pasture and hay, available for livestock in Florida.

By 1941 more work had been done on the growing of winter clovers in Florida. Blaser and Boyd (3) co-authored Experiment Station bulletin 351 which added impetus to the planting of southern grown white clover seed along with improved cultural techniques.

For a number of years various crotolaria species were under study to determine their forage value. Bulletin 361, "Crotalaria for Forage" by Ritchey *et al* (16) published in 1941, points up the final word on this summer legume. *Crotalaria incana* and *intermedia* were found to be preferred by livestock over all other species; however, none of the crotalaria species have ever developed in Florida to the extent of being a major economic crop in livestock production.

Annual lespedezas came into some prominence from central and north and west Florida during the early 1940's. Warner and Blaser (20) summed up results of a number of experiments in bulletin 375 with recommendations for growing Kobe, Common and Tennessee 76 varieties of lespedeza. For several years it appeared lespedeza would have a permanent place in the pasture program of this state; however, by 1950 very few new seedings were being made. Only minor isolated areas in Florida now consider lespedeza as an economic crop.

Difficulties with the growing of both legumes and grasses persisted, and by 1943 data were in hand pointing to the lack of certain minor elements in some soils as a prime reason for certain failures. Bulletin 384 by Killinger *et al.* (8) summarized investigations on pasture plants with minor element treatments. More and more pastures were treated with minor elements resulting in increased production of forage and improved longevity of the species.

The year 1943 was a most important one in the history of pasture development in Florida with the release of four new grass varieties. Pangolagrass was released to farmers for planting after being tested for several years in pasture grazing experiments. Pangolagrass was an immediate success as evidenced by the many requests for planting material. This new grass came to Florida first in 1936 by way of plant introductions from South Africa by way of the United States Department of Agriculture. The same year results were available on one year's grazing of a new bahiagrass promptly named Pensacola bahia. This new variety of bahia was first discovered by Mr. E. Finlayson, County Agent in Santa Rosa County, Florida. Pensacola bahia was quickly accepted by cattlemen and its acreage was rapidly increased. This became the first bahia variety which could be rapidly established from seed; luckily, it was also a prolific seeder. Vegetative material of Coastal and Suwannee bermudagrasses also became available for release. The two bermudas were hybrids developed by Glenn

Burton of the Coastal Plain Experiment Station, Tifton, Georgia. Experimental grazing and forage yield data showed these two bermudagrasses to be far superior to existing bermuda varieties. There are now approximately 500,000 acres of pangola, 1,200,000 acres of Pensacola bahia, 100,000 acres of Coastal bermuda and 15,000 acres of Suwannee bermuda grasses grown in Florida.

During the mid-1940's, several legumes showed promise of improving the quality of pasture forage, namely, Black Medic, California bur and Hop clover. By 1950 none of these legumes had been generally accepted and only a limited acreage is now grown. Kenland, Louisiana and Nolin's red clovers have been proven adapted to a considerable area in Florida with several thousand acres planted annually. Alfalfa, particularly the variety Hairy Peruvian, was found adapted to the Florida peninsula soils and climate in 1948 after five years of research, and the acreage of this crop has increased to some 20,000. Alfalfa in Florida is grown primarily by dairy farmers and is fed either green-chopped or as hay.

By 1949 Hairy Indigo, both common and an early flowering strain, had been proven both as a good grazing summer legume and as a desirable cover crop. Early results and cultural requirements of this legume were pointed out by Ritchey (15) in press bulletin 624 published in 1946. Today over 200,000 acres in the Florida peninsula are planted to Hairy Indigo for grazing and soil improvement.

An oat breeding program conducted by personnel at the North Florida Station, Quincy, and the Agricultural Experiment Station at Gainesville resulted in the release of new high forage and grain producing varieties during the 1940's and 1950's. Oats are now planted on some 150,000 acres annually with most of it used for grazing. Oats have added materially to the supply of green winter feed as noted by Killinger, Glasscock and Stokes (9) in press bulletin 627. Baker (1) summarized some profitable experimental results on winter oats and crimson clover pastures in bulletin 458. Both oats and rye are recommended for northern Florida by Litzenberger, Chapman and Carver (13) in press bulletin 653. The expansion in oat and rye acreage now grown in Florida can be directly attributed to the breeding and release of disease resistant high yielding strains now offered for sale.

By 1949 with winter clovers being grown from one end of the state to the other, Hodges, Jones and Kirk (6) reported results and made recommendations for growing winter clovers on south Florida flatwoods soils in press bulletin 654.

In 1950 some five counties in south Florida asked permission to plant Torpedograss under the Federal and State Agricultural Program. About the same time Hodges and Jones (5) published cultural recommendations for its production in circular S-14. After a few years, most ranchers in those counties abandoned Torpedograss and favored Pangola, Pensacola bahia, Para and Carib grasses in its place.

By 1951 another new variety of bahiagrass was released known as Argentine bahia as reported by Killinger *et al.* (11). Argentine bahia is now planted on about 100,000 acres of Florida's pasture land.

Floranna sweetclover was developed in Florida and released in 1952. The culture of this productive annual white sweetclover is given in circular S-46 as reported by Killinger (7). Both Floranna and Hubam clovers came into prominence in the Florida pasture program; however, today less than 50,000 acres are seeded annually.

The virtues of Big Trefoil, a perennial legume, were extolled by Wallace and Killinger (18) in 1953 and reported in circular S-49. Big Trefoil, as of now, has failed to meet the forage expectations of cattlemen and only a few farmers have made plantings.

Pearlmillet (Cattail), while not a new grass, became an important summer annual grass for both dairy and beef cattle between 1939 and 1959. Nearly 100,000 acres of this grass are now grown in Florida. New adapted varieties with more leafiness have been released by the Georgia Coastal Plain Experiment Station as Starr and Gahi varieties during the past several years. During 1958 and 1959, more acreage of these new millet varieties have been seeded than heretofore.

It can truly be said that pasture herbages during the past two decades have gone or progressed from rags to riches. Prior to 1939 most of the area pastured in Florida was supporting poor to good stands of Carpetgrass and Wiregrass, and now over 2,000,000 acres of pasture land are planted or seeded to Pangola, Pensacola bahia, Coastal bermuda and clover. Prior to 1939 five to 15 acres of pasture land were required to support each cow, and by 1959 only one to two acres or less was the requirement. Beef yields in terms of pounds of beef per acre increased during the same period from five to 30 pounds per acre to 200 to 1,000 pounds per acre.

Not all the credit of increased livestock production can be credited to new pasture plants, because improved fertilization, minor element treatments, management, cattle prices and type or breeding of cattle are all closely interwoven during this period of two decades just past. Federal aid to pasture development plus pasture research and improved livestock have helped place Florida 13th in numbers of beef cattle in the United States.

One cannot but marvel that during this 20-year span over three-fourths of Florida's total improved pasture acreage is now supporting forage species not even heard of in 1939, or at best only a few acres were in existence.

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Changes in Pasture Fertilization[1]

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In the preparation of a review paper of this type it is difficult to obtain a sharply defined starting point, since time is required to convert an idea into an experiment, and an additional period is necessary to present experimental results in a publication. Likewise, it is not always easy to give proper credit to each research contributor, as the development of much of the pasture research follows a rather uniform pattern based on previous knowledge and current requirements. This often leads to nearly identical ideas and similar experiments and conclusions by men working independently on pasture problems. In the preparation of this paper, literature citations were selected on the basis of representative papers that fell into a stepwise development of pasture fertilization in Florida. Failure to recognize some contributions by literature citations should not be construed as a failure to recognize the importance of these contributions to the development of pasture fertilization in Florida.

PASTURE FERTILIZATION TO 1939

Probably the greatest challenge to the pasture fertility program in 1939 was based on the work of Blaser and coworkers who had determined that whiteclover could be grown in Florida. An early bulletin on the subject (4) was admittedly, by title, a preliminary report, and although a complete plan of the experiment is reported, no data are presented. This is typical of early experiments, since planting methods, innoculation and clover strains undoubtedly had more effect on yields than the rates of fertilizer used. Nonetheless, a recommendation of one ton of lime, 600 pounds of superphosphate and 100 pounds of muriate of potash was offered, based on 1937-38 results. Further additions of manure and light applications of nitrogen fertilizers seemed to additionally benefit the clover growth.

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Grass fertilization experiments had been in progress for many years. Under Hatch Project 27, Stokes, Ritchey and Leukel (37) reported on eight years of fertilization of bahia-centipedegrass pasture. Their top rate of fertilization, 600 pounds annually of 8-12-6 plus 600 pounds annually of hydrated lime, produced an annual average dry weight yield of 1,648 pounds per acre. This was nearly 1100 pounds better than the unfertilized check. Blaser and Stokes (7) reported top yields from carpetgrass of 2068 pounds dry weight per acre, using 2000 pounds of lime, 400 pounds of superphosphate, 100 pounds of muriate of potash, 200 pounds of nitrate of soda and 200 pounds of sulfate of ammonia. The following year Blaser and Stokes (8) reported yields up to 3300 pounds of dry weight per acre with this same fertilizer treatment. At the same time they reported a test on nitrogen sources with split applications totaling 48 pounds of N from each source. The additional yields from the nitrogen in pounds per acre of dry material were approximately 1000 pounds for nitrate of soda, 900 pounds for sulfate of ammonia, 540 pounds for Uramon and 450 for calcium cyanamide. While these yields were not spectacular, they correspond well in relative order with observations made under similar soil conditions in more recent years (9, 38).

Grass varieties generally used for tests at this time had such low potential yield responses to fertilization that it is not surprising that there seemed to be little future for fertilization of grass pastures in Florida. On the other hand, the responses obtained with clovers were attracting considerable attention. Significant responses to lime had not been obtained on the grasses, but the need for lime became immediately apparent when clover was grown. The grasses used had shown but little response to phosphate and potash and, although responses to nitrogen were usually obtained, they did not appear large enough to justify the cost. However, clovers were responding to both phosphate and potash and if properly inoculated required no nitrogen.

Fertilization practices reflected a general fear of over-liming and rates exceeding one ton of lime per acre were seldom employed even in experiments. Earlier reports of phosphorus deficiency in range cattle (2) and the generally low cost per unit of phosphates as compared with nitrogen and potash fertilizers were probably factors influencing the high rates of phosphates used in these experiments. The secondary value of calcium in rock phosphate and even in superphosphate may also have been an important factor in those experiments where the rate of liming was low. Minor elements were suspected of being important, but positive data were generally lacking.

Plant analyses of pasture herbages from these experiments were usually omitted, although some sporadic work was done, particularly for total nitrogen or protein. Likewise, soil analyses in conjunction with pasture experiments were seldom performed except for a few pH determinations.

PASTURE FERTILITY EXPERIMENT DURING EARLY YEARS OF S. S. S. F.

The Soil Science Society of Florida recognized the importance of pastures and held its first pasture symposium in 1941 as reported in Vol. 3 of the Proceedings. Particularly noteworthy were Warner's conclusions (40) that soils in northwest Florida required superphosphate for growth of whiteclover and annual applications of superphosphate and potash

would be necessary to maintain the stand of clover. Similar conclusions came from work at the West Florida Station a number of years later (22). Also setting the stage for future work was the report of Blaser, Smith, and Volk (6) at this symposium which showed that plant species used for pastures differ greatly in their nutritional requirements, and emphasized the importance of studying nutritional requirements of individual plant species on various soil types.

Two years later Blaser (3) felt that responses to fertilizer nitrogen were uneconomic for beef cattle production but could be of benefit in dairy and poultry pastures. He also recognized the probability that the then recommended 0-14-10 legume fertilizer did not supply adequate quantities of potash. In discussing phosphate sources, he mentioned the possible shortage of sulfur in phosphate sources other than superphosphate.

Numerous minor element tests were initiated and, although plant growth responses were often difficult to measure, it became apparent that boron was needed on clover in many areas (29), and copper, zinc and manganese were stimulating grass and or cattle growth (23, 29). High levels of molybdenum were noted in herbages from some peat soils and in clover on sandy soils (15) fertilized with as little as one pound of molybdenum per acre. Cobalt, although apparently not required for plant growth, was found to be in short supply in some areas where a nutritional anemia of cattle was observed (1, 11).

At the close of the World War II, the ability of the newer grasses to respond to higher rates of fertilization was still largely unrecognized. Carpetgrass was recommended for use in basic fertility experiments because, in terms of total acreage, it was the predominant grass. Although different herbage and beef yields were being obtained on the newer grasses (24), fertilizer recommendations for all grasses were essentially the same. A 6-6-6 fertilizer at 400 to 500 pounds per acre was the basic recommendation, although most pasture workers agreed that if they could get the average cattleman to use half this amount it would be a major accomplishment. The ideal pasture (5) was a clover-carpetgrass mixture planted on flatwoods and fertilized annually with 500 pounds per acre of 0-14-10. However, a few cattlemen were exceeding the ideal with clover-common bahiagrass pastures.

Considerable improvement was made in innoculation of clovers (34) as well as in cultural means for establishing new plantings of recently introduced grasses. New and improved heavy equipment was being developed to speed land clearing and establishment (27) of new pastures. Meanwhile, for the economy-minded, Killinger (28) converted the old habit of woods burning into a cheap method of land preparation for the seeding of clovers and improved grasses in undeveloped areas. This was undoubtedly a major factor in the rapid increase in clover planting in Florida. The need for increased replication of plots so that data could be treated statistically was beginning to receive major recognition.

RECENT DEVELOPMENTS IN PASTURE FERTILIZATION

Rather rapid changes in the concepts of pasture fertilization began to take place in the late 1940's. Chemical analyses of both herbage and soil were used more extensively. Results from these studies led to numerous exploratory type experiments and the ideas upon which these experiments

were based were being adopted by ranchers faster than the requirements for statistical significance in the data could be satisfied.

Out of these experiments emerged a sound evaluation of the relative production potential of the various pasture plants. Studies of the individual species revealed different nutrient requirements and some practical information on what constituted low, normal and luxury consumption levels in the plant (17, 19). The rapid growth of some of the more recently introduced grass species resulted in protein levels even lower than those in the poorer slow growing grasses. The need for higher levels of nitrogen in the fertilizer was recognized and a whole host of new experiments were initiated (10, 11, 26, 30, 39).

The role of soil in pasture nutrition was more fully evaluated with the recognition of the need for lime, not only for the sake of the calcium and magnesium supplied, but also for its value in conserving potassium and phosphate supplies (33). The gradual accumulation of phosphate in properly limed and fertilized pastures has resulted in a decrease in the quantity of phosphate required for fertilization of these older pastures. The importance and need for sulfur was clearly demonstrated (34).

The recognition of the limitations and advantages of various types of pasture experiments has done much to improve our knowledge of pasture nutrition requirements. For example, potash responses observed by the senior author in clipped plot experiments led to the recommendation (20) of some rates of potash fertilization that may have been in excess of the requirements of most grazed clover-grass pastures.

It was soon realized that the higher rates under some pasture conditions were not producing the additional herbage growth observed in the clipped plots. The efficient absorption of potash by the plant and its subsequent complete removal from the plot by the clipping process was not fully appreciated. More recent experiments (21), in which the herbage was grazed in place instead of being clipped and removed, indicate that the recirculation of potash may actually provide four times as much potash for the plants under grazing conditions as under clipping. Somewhat similar observations have been made for phosphate and nitrogen (10, 35).

Some unirrigated clipping experiments have indicated the possibility of continued response to nitrogen rates of 400 to 500 pounds per acre per year (11, 30, 39). Actual grazing experiments (10, 21, 25) seem to point to the fact that under these conditions a maximum may be reached at something less than an annual total of 300 pounds of nitrogen per acre. Moreover, with favorable moisture conditions and clover strains capable of surviving through the summer, the total nitrogen requirement under these conditions may be met by that fixed by the clover. Adverse weather and or less than ideal pasture management systems may continue to send the cattleman to his nitrogen fertilizer supplier when it seems desirable to keep the grass portion of a clover-grass pasture in top production.

These findings have brought the differences between systems of pasture management into sharp focus. Systems which involve only the removal of herbage by grazing will require much less total fertilizer than those which involve removal of all or part of the herbages for silage, hay or other purposes. Most intensive fertility studies in Florida have been based on systems of all grazing or all herbage removal and almost all recent recommendations have been based on all grazing systems. Many a Florida cattleman has found to his sorrow that the removal of a fine hay crop from a pasture without immediate refertilization has practically stopped further

growth on that field. Appreciation of the fertility cycle on sandy soils that have relatively little ability to retain a reserve of plant nutrients, especially potash and nitrogen, is essential in maintaining a pasture fertility program.

Measurement of the trace element requirements for pastures has continued to be a difficult task. However, there has been an increasing trend towards the inclusion of boron, copper, zinc and manganese in pasture fertilizers as a general insurance factor. Recent tests with trace element frits (16) indicate that these materials may remove some of the complications involved in trace element experiments on pastures.

In addition to actual fertility requirements of pasture grasses, recognition of the temperature or climatic responses of these grasses (18, 31, 32) has been of major importance in determining their advantages and limitations and in adjusting fertility programs accordingly. In the northern half of the state, it has been possible to make some very definite recommendations as to date and rates of fertilization for reserve winter feedings (18). The problem in the southern part of the state is complicated by more irregularity in winter temperatures which make general recommendations more difficult (31).

SUMMARY

Pasture fertility research has matured considerably in the past twenty years. The older systems were based to a large degree on "cut and try" procedures with relatively limited knowledge of the actual plant requirements or soil conditions. Today, initial evaluation of the nutrient and environmental requirements of the individual pasture herbages is basic for a successful experiment. An extended knowledge of the capacities and limitations of the soils in the retention of moisture and plant nutrients has taken much more of the guess-work out of planning fertilizer rates and ratios. A better appreciation of the nutritional requirements of the grazing animals (13, 14) helps to mold pasture experiments towards establishment of pasture conditions more suitable for maximum animal nutrition. The current trend towards establishment of fertilizer ratios that will insure that every unit of plant food will carry its full load in the production of pasture herbage is leading us to the point of maximum quantity of quality herbage per fertilizer dollar.

Of even more importance than the present value of these data is the fact that pasture research over the last twenty years represents the beginning of the accumulation of a large body of fundamental knowledge on nutritional interrelationships among soils, plants and animals. The current maximum economic rate of pasture fertilization, management and production could be altered overnight by a change in the world or even the local economic situation. With a body of fundamental data available, a new maximum could be quickly calculated without resorting to the slow laborious "cut and try" method of pasture experimentation which is fortunately rapidly becoming a thing of the past.

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The Evaluation of Cold Hardiness in Florida Pasture Grasses[1]

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Attention was strongly drawn to the subject of cold hardiness by the severe winter experienced in Florida in 1957-58. Pasture grasses were subjected to repeated freezes, excessive rain, and high winds which brought about severe losses. December, January, and February of that winter season are alleged to have been the coldest consecutive three months which have ever been experienced in Florida. That severe winter, however, only focused attention more strongly on a subject which has for a long while been in a position of prominence in agriculture. The recognition of a need for hardy plants has been a motivating factor in plant breeding programs and in the basic botanical sciences.

One prime objective of hardiness studies has been to obtain quantitative measurements of the degree of cold hardiness exhibited by plants under varied conditions such as different fertility levels.

With the tremendous interest in cold hardiness, it is only to be expected that a large body of literature concerning the subject is in existence. Reviews of prominence were published by Rosa in 1921 (11), Levitt in 1941 (8) and 1956 (9), and Dexter in 1956 (5).

Numerous methods have been used to evaluate plants as to cold hardiness. Observations of a plant's ability to survive a winter in the field have

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probably been most widely used in testing for cold hardiness. Although this is good in that it tests plants under natural conditions, it has the disadvantage of the possibility of long periods of mild winters before a real test winter occurs.

Briggs and Siminovitch (1, 14) have used percent of survival of cells after dehydration by plasmolysis as a cold hardiness test. In order to obtain plasmolysis, they subjected tissues to a graded series of strong salt solutions. In other work, they (15) have also used desiccation tests to determine hardiness. In these tests, cell survival was noted after desiccation in atmospheres of varied relative humidities. A graded series of sulphuric acid solutions was used to produce the different atmospheres.

Conductivity tests have been suggested by Dexter *et al* (3, 4) as a means by which plants can be rated numerically as to cold hardiness. They have assumed that there is a correlation between the degree of injury from low temperatures and the diffusion of electrolytes after plant cells have been exposed to cold. Electrical conductivity readings that measure the amount of electrolytes which have diffused outward are used to estimate the degree of injury.

A number of workers, including Grandfield (7), Ruelke and Smith (12), Bula and Smith (2), Megee (10), and Silkett *et al* (13) have used the conductivity method in their studies of cold hardiness of different forage plants.

Dexter (5) has taken Bula and Smith to task for an attempt to compare winter hardiness of species without determining percentage of extraction of electrolytes. He indicated that in order to make comparisons it was necessary to allow for extraction of all electrolytes and determine the percentage which were extracted following the freezing treatment. Dexter used a process which involved the placing of the tubes containing the samples into boiling water in order to extract all the electrolytes. Boiling has also been used by Stuart (16) and Emmert and Howlett (6).

MATERIALS AND METHODS

A study was carried out in the winters of 1957-58 and 1958-59 in which the electrical conductivity method was used to indicate cold hardiness differences in two grasses at different levels of nitrogen applications. This experiment utilized grass samples from plots of Pensacola bahiagrass (*Paspalum notatum* Fluegge) and pangolagrass (*Digitaria decumbens* Stent.). These plots were established in 1956 on Arredondo loamy fine sand and have been maintained at the specified levels of fertility. The fertility program included an annual spring application of 500 pounds of 6-6-6 commercial fertilizer per acre to all plots, with treatments of varied rates of ammonium nitrate. Equal applications of ammonium nitrate were made in May, July, and September to bahiagrass and in May, June, and July to pangolagrass at a rate which provided yearly nitrogen levels of 100 and 400 pounds of nitrogen per acre per year on each of the two grass species.

Whole plants were removed from the plots during the winter period and test samples of bahiagrass were prepared. Samples consisted of the one and one-half inch portion of rhizone just below the crown and the top growth one and one-half inches immediately above the crown. The samples were rinsed three times in deionized water, wrapped in cheesecloth, and dried by a slinging motion.

The same procedure was followed for pangolagrass samples except that the sample consisted of the crowns and the above-ground growth to a length of two and one-half inches.

Five-gram samples were placed in test tubes and submitted to a cold treatment of −4° C. for 24 hours in a deep freeze. At the termination of the freezing treatment, 50 milliliters of deionized water were delivered to each tube by pipette and a period of 20 hours at room temperature was allowed for diffusion of electrolytes.

After the diffusion period, all samples were brought to and maintained at 25° C. in order that resistance readings could be taken with a Model C Bouyoucos Bridge. Readings of resistance were taken on the solutions from the tubes and specific conductance was computed.

During the 1958-59 winter, percent of total conductivity was determined in order that the two grasses might be more accurately compared and that the two fertility levels might also be more accurately evaluated. Following the determination of specific conductance the percentage of total conductivity was determined by compositing of the contents of two tubes and grinding in a Waring Blender until a homogeneous mixture was obtained. This mixture was then filtered through a number one Whatman filter and a resistance reading was taken on the filtrate. The specific conductivity was calculated from an average of the readings from three sets of two-tube composites. This figure was taken to the the total conductivity for the grass from that particular fertility level on that particular test date. Utilizing this number and the specific conductivity determined for the individual samples following the freezing treatment, the percent of the total conductivity was determined for the various samples.

RESULTS AND DISCUSSION

The data for bahiagrass during the 1957 season are given in Figure 1. These data indicate that during the first three observation dates the plants fertilized at the 400 pound level of nitrogen were hardier. The observation made December 16 indicates that a higher degree of cold hardiness was then possessed by the grass grown at the 100 pound level of nitrogen.

A somewhat contrasting picture is given in Figure 2 for pangolagrass during the 1957 season. These data indicate that cold hardiness was greater in pangolagrass at the lower fertility level during the first three observations dates. On the last observation date, the reverse is true, but the difference in the conductivity values for the samples at the two fertility levels is extremely small.

Yield data and estimations of winter injury given in Table 1 indicated that winter injury was approximately equal at the two fertility levels in bahiagrass during the winter of 1957-58 but that injury was considerable more severe at the 400 pound level in pangolagrass.

The experimental emphasis for the winter of 1958-59 was placed on the results as indicated by percent of total conductivity. The study was divided into six periods with each consisting of three observation dates. These data are summarized in Figure 3. The overall statistical analysis for the 1958-59 study is given in Table 2. These data indicate the presence of differences in hardiness between the two grasses and between fertility levels and that an interaction was present between grasses and fertility levels. No attempt will be made here to present the complete statistical

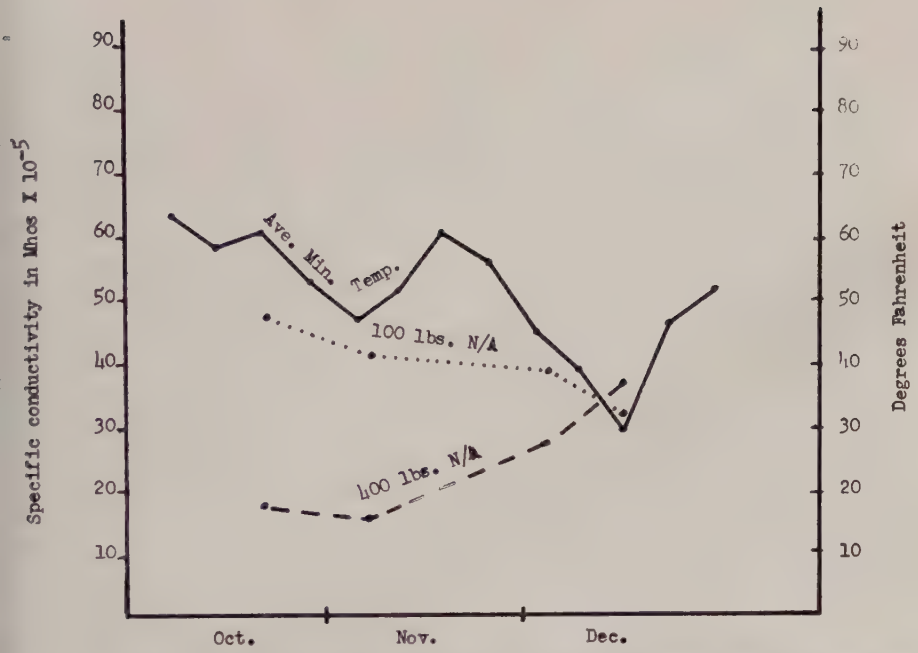

Figure 1.—Comparison of specific conductivity at the two fertility levels in bahiagrass in 1957 with average weekly minimum temperature.

breakdown of the study; however, certain general observations will be made.

In Figure 3, values of percent of total conductivity are presented for the various periods. One may see from this graph that during most of the season the highest values are exhibited by pangolagrass. Higher values for percent of total conductivity indicate less cold hardiness in the plants. Greater fluctuation among fertility levels as to degree of cold hardiness was noted in pangolagrass, while the 400 pound level of nitrogen consistently produced the more cold hardy samples in bahiagrass.

Pangolagrass was more severely injured during the winter of 1958-59

TABLE 1.—FORAGE YIELDS AND ESTIMATIONS OF WINTER INJURY

Grass	Fertility Level (Lbs. N)	Total Yield 1957 (Lbs.)	Est. Winter Injury 4/14/58 (%)	Dry Matter Per Acre First Cutting 5/26/58 (Lbs.)	Total Yield 1958 (Lbs.)	Average Nitrogen Content (%)	Est. Winter Injury 3/23/59 (%)	Dry Matter Per Acre First Cutting 5/26/59
Pangolagrass	100	5595	26.7	271	3198	1.43	5	497
	400	11441	80.0	65	8192	2.47	13	737
Pensacola Bahiagrass	100	5975	0.0	1515	6345	1.20	2	857
	400	13935	0.0	3958	15145	1.76	2	2467

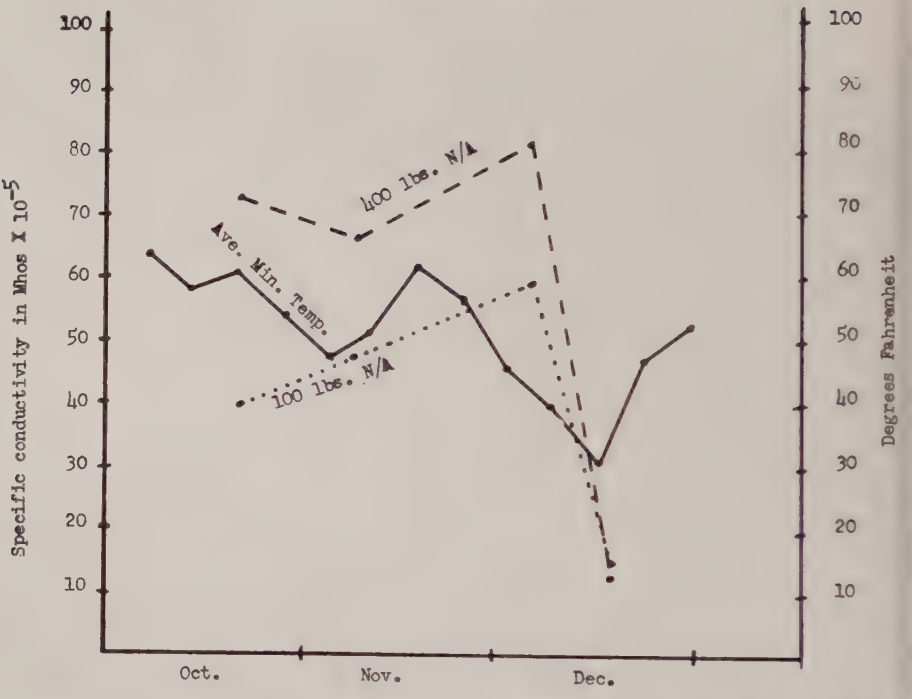

Figure 2.—Comparison of specific conductivity at the two fertility levels in pangolagrass in 1957 with average weekly minimum temperature.

TABLE 2.—ANALYSIS OF VARIANCE: PERCENT OF TOTAL CONDUCTIVITIES OF TWO GRASSES IN EACH OF SIX PERIODS AS AFFECTED BY FERTILITY TREATMENT DURING 1958-59 SEASON

Source	D.F.	Sum of Squares	Mean Square
Main Plots:			
Replications	2	73.99	
Periods	5	96.88	
Error (a)	10	2,558.24	
Subplots:			
Grass	1	11,865.70	11,865.70**
G x P	5	1,991.78	398.36**
Error (b)	12	992.82	82.74
Sub-subplots:			
Fertility levels	1	1,423.10	1,423.10**
F x P	5	780.09	156.02*
F x G	1	411.38	411.38**
F x P x G	5	509.12	101.82
Error (c)	24	1,099.66	45.82
Total	71	21,802.78	

* Significant at 5 percent level.
**Significant at 1 percent level.

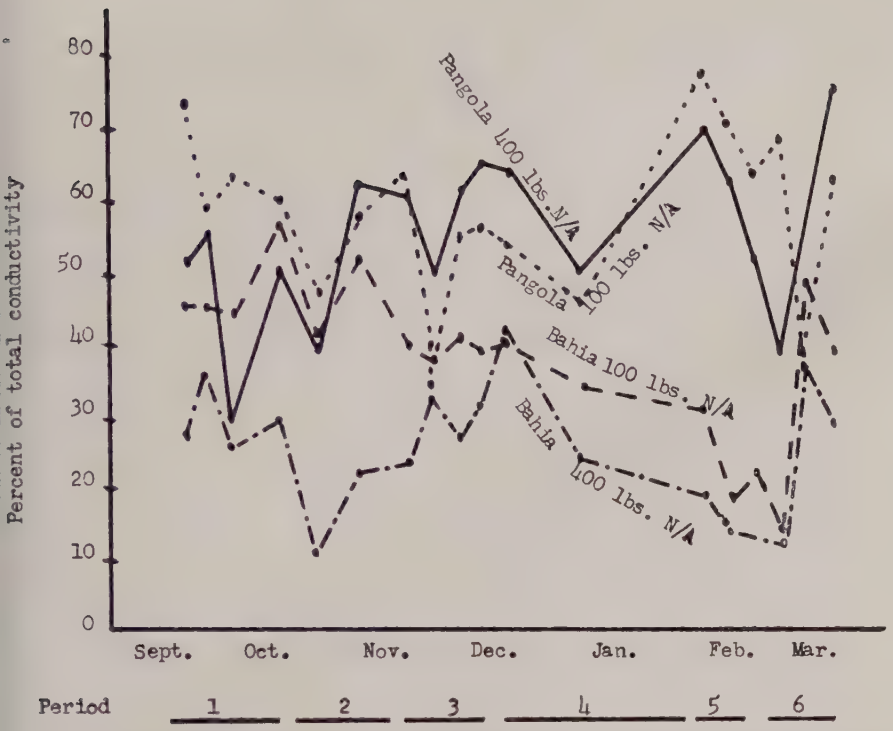

Figure 3.—Comparison of values of percent of total conductivity between the two fertility levels in the two grasses during the 1958-59 season.

than was bahiagrass. Yield data given in Table 1 show that greater injury was probably suffered by pangolagrass at the 400 pound level of nitrogen while little difference in the amount of injury could be detected between the two levels in bahiagrass insofar as yields obtained from the first cutting in 1959 indicated.

SUMMARY

A method of evaluating Florida's pasture plants as to cold hardiness has been developed and is described in this work. The test is based on the correlation which exists between the degree of injury from low temperatures and the outward diffusion of electrolytes after plant cells have been exposed to cold. Electrical conductivity readings which measure the amount of electrolyte released from injured cells were used to evaluate the degree of injury.

During the winters of 1957-58 and 1958-59, experiments were conducted in which the electrical conductivity method of determining cold hardiness of plants was applied to pasture grasses. Observations were made as to differences between Pensacola bahiagrass and pangolagrass in their relative cold hardiness as affected by nitrogen fertilization. Bahiagrass generally appeared to show more hardiness at the 400 pound level of nitrogen than at the 100 pound level, while a rather wide fluctuation was observed be-

tween fertility levels in pangolagrass. Insolar as winter injury indicated, little difference was observed between the two fertility levels in bahiagrass, while pangolagrass was more severely injured at the higher level of nitrogen.

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Effect of Rate and Frequency of Nitrogen Application on Yield and Quality of Pangolagrass

R. W. Prevatt and J. C. Engibous[1]

More and more acreage of improved pasture in Florida is being developed. From these improved pastures come most of the forage for beef cattle. Improved and adapted species of grasses and legumes along with better grassland management have all contributed to the higher productivity of the pastures. Of the many factors of management, the proper use of fertilizers furnishes the farmer the greatest opportunity to increase his productivity and thereby increase his return on the capital investment represented by his improved pastures.

Pangolagrass (*Digitaria decumbens*) has been available to farmers in the Southeast since 1943, and Florida cattlemen alone now utilize over 500,000 acres of this species (10). Early fertility experiments (1, 7, 9.) established that certain improved and introduced grasses were far more efficient in utilizing fertilizer, particularly nitrogen, than native species. Also, in early research, application rates were not high enough to exploit fully the production potential of these superior grasses. More recently, research workers have attempted to establish the upper limits of forage production by increasing fertilizer application rates to levels which deliberately exceed agronomic and economic bounds. By such techniques, applied on a number of important soil types and crop species under different climatic conditions, the true capacity of grassland crops can be determined.

Production levels of Coastal Bermudagrass and Pangolagrass in Florida have been approximately 10 tons of dry forage per acre from applications of 666 to 1560 pounds of nitrogen per acre (7). In Georgia, the production level of Coastal Bermuda hay was on the order of 16 tons per acre where 900 to 1000 pounds of nitrogen was used in a 4-1-2 ratio with other major fertilizer elements (3). The same crop in Texas has yielded 14.5 tons of forage when nitrogen was applied at the rate of 1,350 pounds per acre (5). Wallace et al (10) obtained responses from Bahiagrass and Pangolagrass with application rates up to 240 pounds of nitrogen per acre per year. Blue and Gammon (2) reported Pangolagrass yield responses up to 288 pounds of added nitrogen per acre in 1954.

The purpose of this investigation was to determine the effect of rate and frequency of fertilization, primarily nitrogen, on the total production of forage and crude protein of Pangolagrass in central Florida grown on a well-drained soil, and to estimate its persistence under conditions of high fertility.

EXPERIMENTAL PROCEDURE

An area of approximately two acres was cleared of the palmetto, scrub oak, and miscellaneous cover by bulldozing in August, 1952. The land was then leveled, plowed, disked, and uniformly limed at the rate of one

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ton per acre. The area was on International Minerals and Chemical Corporation property near Bartow, in Polk County, Florida. The soil is classified as Lakeland fine sand, a yellow Podzolic soil derived from marine deposits of non-calcareous sands and clay. The area had an initial pH level of 5.2. A blanket fertilizer application was made consisting of 300 pounds per acre of 6-6-6 containing 1.5 units each of manganese, copper, and zinc oxides. Pangolagrass was sprigged on September 16, 1952.

The Pangolagrass trial consisted of a 4 x 4 factorial experiment involving four rates of nitrogen (0, 160, 320, and 480 pounds per acre per year) and four times of application (1, 2, 4, and 8 times per year). Treatments were initiated on April 11, 1955. Phosphorus and potassium were applied uniformly as 400 pounds of 0-15-15 semi-annually, since this rate has been shown to be adequate for Pangolagrass. Nitrogen was applied throughout as NH_4NO_3, phosphorus as single superphosphate, and potassium as KCl. All plots were 15′ x 90′, and the harvested area was approximately 1/50 acre.

The grass was harvested when the faster-growing plots attained a height of approximately eighteen inches. Three Pangolagrass harvests were made in the last six months of 1955, four in 1956, four in 1957, and four in 1958. Harvesting was done by a Gravely tractor with a 32-inch sickle bar mower attachment. Samples were taken for dry weight measurements and for protein analysis from each plot for each harvest.

RESULTS AND DISCUSSION

The data presented herewith are from a well-drained soil as contrasted to other data (2, 7, 8, 10) which were taken from flatwood soils, classified as moderately to poorly-drained.

Total forage and crude protein yields recorded over the four-year period are summarized in Tables I and II. The 1955 results do not represent a 12-month period in terms of total application of nitrogen or forage growth and composition. The treatments calling for 4 and 8 application frequencies failed to receive ¼ of the assigned annual rate of nitrogen. In the 6-month harvest period in 1955, dry forage yields were increased significantly by application rates up to the maximum level of 480 pounds per acre in spite of a low moisture year. Crude protein yield values were not quite statistically significant at the 5% level beyond the 160 pound rate. The total forage and protein yield values were more closely associated in Pangolagrass than were found in Bahiagrass grown under similar conditions (4).

In 1956, in which the drought condition continued, applications of nitrogen up to 320 pounds per acre resulted in yield increases of both forage and crude protein. There was a more adequate supply of moisture in 1957 than in 1956. This was reflected in the growth of Pangolagrass. Yield increases were obtained from each increment of added nitrogen, and the protein content of the forage followed the same pattern. In 1958, there were significant increases in the average yield of both forage and crude protein between the 160 and 320 pound rates for all frequencies. This significant difference was found 4 out of the 4 years of the experiment.

There was no consistent trend toward more efficient use of nitrogen by using split applications at any rate. Pangolagrass was found to tolerate single applications of nitrogen up to 480 pounds per acre. This was not the case with Pensacola Bahiagrass (4). It was found that where higher

TABLE 1.—Effect of Rate & Frequency of Nitrogen Application Upon Dry Forage and Crude Protein of Pangolagrass (1955-1958)

Year	Applications Per Year	Rate of Application (Pounds N/Acre/Year) 0	160	320	480	Ave.	0	160	320	480	Ave.
		Dry Forage* Tons Per Acre Per Year					Crude Protein Pounds Per Acre Per Year				
1955											
	1	1.30	2.88	2.29	2.78	2.31	204	580	431	601	454
	2	1.14	2.84	3.44	3.54	2.75	194	536	645	798	543
	4	1.24	2.04	2.84	3.02	2.28	246	424	625	649	486
	8	1.22	2.37	3.18	3.57	2.59	212	418	650	666	487
	Ave.	1.23	2.53	2.94	3.22	----	214	490	588	678	----
1956											
	1	1.63	4.24	3.89	3.87	3.41	294	1169	1185	1154	951
	2	1.88	3.99	4.36	4.02	3.56	333	1124	1206	1196	965
	4	1.74	4.15	4.58	3.88	3.59	312	1135	1361	1193	1000
	8	1.39	3.76	4.83	4.06	3.51	252	994	1532	1142	980
	Ave	1.66	4.04	4.42	3.95	----	298	1106	1321	1171	----
1957											
	1	2.62	5.02	4.70	5.84	4.54	450	1078	855	1296	920
	2	2.65	4.22	5.30	5.70	4.47	483	792	1052	1387	928
	4	2.56	4.86	5.52	485	4.45	456	1084	1099	1238	969
	8	2.56	4.53	5.00	5.12	4.30	499	887	1280	1314	995
	Ave.	2.59	4.66	5.13	5.38	----	472	960	1071	1309	----
1958											
	1	1.38	3.96	4.32	4.22	3.47	200	860	974	1000	758
	2	1.43	2.90	4.19	3.67	3.05	211	510	887	768	594
	4	1.39	3.61	3.91	4.33	3.31	209	695	759	947	652
	8	1.27	3.06	4.00	4.41	3.18	185	511	796	978	617
	Ave.	1.37	3.38	4.10	4.16	----	201	644	854	923	----

TABLE 1.— (Continued)

	1955		1956		1957		1958	
Least Significant Difference	.05	.01	.05	.01	.05	.01	.05	.01
Yield (Tons)								
2 rates as average of all frequencies	.31	.41	.34	.45	.48	.66	.39	.53
2 rates at only one frequency	.62	.82	.67	.90	.97	1.32	.78	1.05
Protein (Pounds)								
2 rates as average of all frequencies	100	133	99	132	85	117	71	97
2 rates at only one frequency	200	267	198	265	171	233	143	194

*Each Value is the total of an average of 4 replications per cutting date (4 cutting dates per year)

TABLE 2.—A FOUR YEAR EFFECT OF RATE AND FREQUENCY OF NITROGEN APPLICATION UPON DRY FORAGE AND CRUDE PROTEIN PRODUCTION OF PANGOLAGRASS

Applications per year	Rate of Application (Pounds N/Acre/Year) 0	160	320	480	Ave.
		Total Tons* Dry Forage Per Acre			
1	6.93	16.10	15.20	16.71	13.73
2	7.10	13.95	17.29	16.93	13.92
4	6.93	14.66	16.85	16.08	13.63
8	6.44	13.72	17.01	17.16	13.58
Ave.	6.85	14.61	16.59	16.72	
		Total Pounds* Crude Protein Per Acre			
1	1148	3687	3445	4051	3083
2	1221	2962	3790	4149	3030
4	1223	3338	3844	4027	3108
8	1148	2810	4258	4100	3079
Ave.	1185	3200	3834	4081	

Four Year Totals; 1955, 1956, 1957, 1958.

rates of nitrogen were applied on Pangolagrass grown on flatwoods soil, higher beef gains per acre were produced (7). Also, at comparable rates of nitrogen, the Pangolagrass produced higher beef gains than either Pensacola Bahiagrass or Coastal Bermudagrass grown on similar soils. The conclusion from this data is that nitrogen application rates up to 320 pounds per acre per year in semi-annual applications are justified on Pangolagrass pastures on well-drained sandy soils. The grower, therefore, would be restricted more by economic than agronomic factors in developing a fertilization program.

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TWENTY YEARS OF PROGRESS IN RESEARCH ON PRODUCTION OF GENERAL FIELD CROPS IN FLORIDA

A Review Of Plant And Water Relations[1]

G. M. PRINE AND S. H. WEST[2]

THE ROLE OF WATER IN PLANTS

Water is required by plants in greater quantities than any other compound or element. For each pound of dry matter in a living plant, there are on an average 10 pounds of water. Furthermore, for each pound of dry matter produced, a plant must absorb several hundred pounds of water (2). Water is to plants, as to all living organisms, the very essence of life.

One of the earliest attempts to assign a role to water in plant growth was made by Helmont shortly after 1600. He grew a willow tree in soil adding nothing but water over a five-year period. Since the tree increased in weight by 164 pounds and the soil only decreased by two ounces, he concluded that the tree used water as food (9). This is, of course, an extreme exaggeration of the role of water in plants. However, plant growth is dependent upon a large water use, the requirement of which falls within close limits. Because water is so commonplace, abundant, and usually so inexpensive, its importance is minimized in our everyday plant growing efforts.

Because of the unique physical and chemical properties of water, plants use it in innumerable chemical and physical reactions and processes such as:

1. Expansive growth

Plant growth can be described as a two-step process in which cells increase in number and size. The force by which a newly formed cell increases in size or an older cell retains its size is caused from the turgor pressure created inside the cell which is due to water absorption. Mechanical strength also results from this hydraulic pressure and from the great tensile strength of water. Tensile strength of water has been measured which is equal to that of steel (6). In older cells, the cell wall adds to the strength of the overall plant.

2. Transportation system

Water is used throughout the plant as a transportation medium for nutrients and carbohydrates. Because of its hydrogen bonding and dipolar-solvent action (6), water is probably the medium through which alcohols, organic acids, amino acids, proteins (enzymes) and many other metabolites are transferred.

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3. Chemical reactions

Water enters into many reactions due to its ability to participate by hydrogen, electrostatic or covalent bonding. A water molecule may contribute an oxygen atom and a hydrogen atom to a compound, as in some of the respiration reactions. Whereas, in photosynthesis a hydrogen atom only is taken from water and combined with carbon dioxide to form eventually a carbohydrate molecule. In other reactions such as the splitting of starch, protein, sucrose and high energy phosphate compounds, the water molecule contributes to the reaction by adding hydrogen and oxygen to two separate compounds. Indeed, every organic molecule in plants contains either hydrogen or oxygen and in most cases both.

4. Temperature regulator

Water resists temperature changes because of its high specific heat. Heat is dissipated from plants through the evaporation of water. For every gram of water that is evaporated, 575-594 calories of heat are absorbed at the range of ambient temperatures commonly associated with plants. Similar amounts of heat energy are released when water vapor condenses on plants in dew deposition.

5. Constituent part of plants

Living plants are, for the most part, water in some form. Even when crops are harvested, they may contain as much as 70% moisture. An immature plant may contain as much as 90% moisture. Protoplasm is from 90-95% water and vacuolar sap is 98% water.

THE EFFECT OF INSUFFICIENT WATER IN PLANTS

The results of many investigations show that a water deficiency reduces the total yield of plants. Without doubt, the reduced plant growth is a result of the effect of limited water on many individual plant reactions and processes. Probably the two most important effects are a reduction in photosynthesis and an increase in respiration. This would reduce the carbohydrate and the free amino acid levels, slow protein synthesis and finally cause protein hydrolysis, all of which have been observed in experimentation (3).

FACTORS AFFECTING THE AMOUNT OF WATER IN PLANTS

There is a voluminous and interesting historical account of the attempts to ascertain the force responsible for the entry and passage of water through plants. There is now general agreement that there is an active and a passive movement of water into and through plants (3, 9). The active absorption of water depends upon the imbibitional force created by water being absorbed by colloidal materials and osmotic forces resulting from an accumulation of nutrient and organic materials inside a semipermeable membrane. The evidence which implicates metabolism involvement in active water movement comes from the observations that increased respiration and auxin additions increase water absorption.

Although there is conclusive proof that water is absorbed and moved

through plants by active forces, the water supplied by these processes is of minor importance in the total water economy of most plants. The tension developed and transmitted through the continuous water system as a result of evaporation of water from the leaves is responsible for the major water supply in plants. This tension is caused and conditioned by external forces and the plant is for the most part only conducting tissue.

Some factors affecting the amount of tension developed in the water column of plants are:

1. Size of stomata
2. Opening and closing of stomata
3. Diffusion pressure deficit
4. Movement of air over the leaf surface
5. Temperature
6. Water conducting capacity of the tissue
7. Availability of water to the plant root

The availability of water to the plant is influenced by the size of root system and the supply of water in the soil (15, 20). In Florida most of our research has been centered around maintaining an adequate supply of water in the soil.

WATER NEEDS OF PLANTS IN FLORIDA

The soils of Florida are predominantly sandy, so fertility and water holding-capacity are generally low. Many of these soils have in their profile a layer resistant or impervious to downward movement of water. Large areas of flat land with high normal or perched water tables coupled with high rainfall makes drainage an important factor in water management.

The state of Florida would soon be a lifeless desert if it were not for the continuous movement of water in the "hydrologic cycle." The water vaporized by evaporation from soils and various water surfaces and transpiration from plants is returned to the earth from the atmosphere as rain, dew and other forms of precipitation. Though water movement in the hydrologic cycle is continuous, the rate of water movement may vary. The net results are droughts on one occasion, floods on another and the many problems that come with fluctuating ground and surface water supplies.

The principal natural source of water to plants in Florida is rainfall. The average rainfall for different station locations in Florida varies from about 50 to 65 inches annually. Some locations, such as the Florida Keys have less than 50 inches. Rainfall is variable in amounts both annually and seasonally. It is not uncommon for the rainfall of a wet year to be twice that of a dry year. Butson (1), who has recently reported on the aspects of rainfall distribution in Florida, points out the variabilities of rainfall distribution which make availability of water to plants a "feast and famine" affair.

Rainfall may be heavy in Florida, especially during tropical storms. As high as 39 inches of rain in 24 hours have been reported during such storms. However, no period of the year is immune to drought, not even during normal "rainy seasons."

The relative benefits of dew and fog as a source of water to plants in Florida is not known. It is entirely possible that some plants may be benefited by water from dew and fog. Went (21) calculates that under optimum conditions as much as 15 inches of dew might be deposited in

single year. Harrold and Dreibelbis (5) have measured an average increase in total water supply in blocks of soils growing various crops of 9.1 inches annually from what they call condensation-absorption. Just what part of their condensation-absorption values was dew is not known. Most quantitative measurements of dew that have been reported are less than two inches of water deposited per year.

A symposium on Florida's water resources and utilization was held at the 1956 meeting of the Soil and Crop Science Society of Florida. The biggest loss of water in Florida is evapotranspiration. An average evapotranspiration rate of .15 inches per day over the entire state would result in a loss of 142 billion gallons of water per day to the atmosphere (4). The significance of this amount is seen when one realizes that the average stream flow per day of all of Florida's streams is only about 40 billion gallons.

The average daily use of water in Florida is estimated to be in excess of two and one-quarter billion gallons (19). Fifty-two percent of this water is used in irrigation, 26 percent by industry, 17 percent for municipal supply and 5 percent for other uses. Ground water furnishes about 60 percent of the water and surface water supplies the remainder.

In south Florida the average evapotranspiration from agricultural crops growing on soils with water table maintained at two feet has been 40-50 inches per year (4). In most instances, the water needs of plants could be satisfied by rainfall if distribution was perfect and no water was lost by runoff and deep percolation. But of course this is not the case, as rainfall distribution is sporadic and runoff and deep percolation normally occur.

McCloud (10) made a study of water use and drought at Gainesville from long-time climatological records; he used an empirical formula to estimate potential evapotranspiration and kept a water budget on two plant-soil water storage levels. When all the available water was gone from the plant-soil water storage capacity of the soil, drought began. McCloud found droughts of approximately 20 days in length in the spring, 15 days in the summer, 25 days in the fall and 15 days in the winter could be expected each year at the two inch plant-soil water storage level at Gainesville. The water use as determined from McCloud's formula appears to be rather high, but his approach does show a good way to further study agricultural drought in Florida. Using a similar method based on Penman's evapotranspiration formula, van Bavel (16, 17 and 18) has participated in making agricultural drought summaries of many of the other southern states.

High rates of evapotranspiration and low-water-storing capacities of soils in Florida combine to make drought conditions develop rapidly. Therefore, a critical shortage of available soil moisture may follow soon after heavy rainfall and a full storage of available soil moisture. Thus irrigation may be needed to prevent serious curtailment of plant growth.

Myers and Skinner (12) reports the results of a survey by Skinner that 19.2 percent of the crop land in Florida was irrigated in 1956. A further breakdown of this survey by crops and acreage is given in Table 1.

Irrigation has often resulted in higher yields of crops and many times in higher quality of crops. This has been substantiated by reports of Florida investigators studying many different kinds of crops. Myers and Clark (11) conclude when irrigation is used properly, the yield of tobacco can be increased 35 to 40 percent and quality improved 5 to 13 percent on the average.

TABLE 1.—TOTAL AND IRRIGATED ACREAGE OF VARIOUS CROPS GROWN IN FLORIDA
(Acreage values are in thousands of acres)

Crop	Total Acres 1954[1]	Irrigated Acres 1956[2]	Percent of Acreage Irrigated
Improved Pasture	1,923	210	9.2
Field (Except tobacco)	1,440	---	
Tobacco	30	9	33.3
Citrus	565	242	42.8
Vegetables and Truck	321	273	85.0
Other (Includes small acreages of field, floral, nursery, greenhouse and other specialty crops)	---	86	
TOTAL	4,279	820	19.2

[1]Source: 1954 Census of Agriculture (preliminary).
[2]Source: Survey of County Agents made by T. C. Skinner (14).
The above table was taken from Myers and Skinner (12).

During a symposium on irrigation problems and crop yields at the 1955 meeting of the Soil and Crop Science Society of Florida, Jamison (7) reported that sprinkler irrigation of fourteen crops of six vegetables at Gainesville resulted in increased yields and better quality, in most instances. Other irrigation research with vegetables at other locations and different types of irrigation discussed by Jamison supported the value of irrigation to increase yields and quality of vegetables and truck crops. Koo and Sites (8), at the same symposium, reported increased fruit set and fruit yields of citrus as a result of irrigation. These workers also stressed the possibility of quality damage to citrus if the proper irrigation management is not followed. Myers and Marshall (13) found that irrigation increased forage yields of white clover–grass pasture.

Poor drainage and low-water-storing capacities of some of Florida soils and heavy rainfall make irrigation a somewhat hazardous undertaking in Florida. Among crops such as vegetables, tobacco and citrus where quality is a decisive factor in production, a heavy rain closely following irrigation may cause a reduction in quality, and when combined with poor drainage can mean total crop loss. However, if rainfall is heavy enough, similar damage could result without irrigation.

Some practices which can reduce irrigation problems to a minimum are:

1. Water Control—maintain soil moisture levels at optimum by irrigation and drainage according to needs.
2. Irrigate only well-drained natural or artificially drained soils.
3. Plant crops tolerant to inundation and water-logged soils.
4. Use water of satisfactory quality and do not over irrigate.

The advantages of applying irrigation water to plants at time of need greatly exceeds any hazard in irrigation, especially where suitable precautions are taken in irrigating.

RESEARCH NEEDS ON PLANT-WATER RELATIONS

As the industrial and urban development of Florida continues there will be increased competition with agriculture for water. Thus it is imperative that the evapotranspiration from all types of vegetation and land areas be determined so the needs of agriculture will be known. Better methods of measuring or estimating evapotranspiration are needed. These should be teamed with historic weather records so as to determine peak water needs and to determine degree and frequency of agricultural drought.

Research is needed to establish more adequately the basic principles and phenomena of water use by plants. Particular emphasis should be given to conservation of water passing through the plant; the absorption, entry and transportation of water in plants; and availability of soil moisture as influenced by physiological and morphological characteristics of plants.

To insure future water needs, the research on reclamation and use of contaminated fresh water, sea water and other wasted water should be continued. All possible sources of water to the plant should be investigated, even dew, mist and fog.

SUMMARY

Large quantities of water are used in plants for a vast number of physiological and chemical processes which include: 1. expansive growth, 2. transportation of materials, 3. metabolic reactions and 4. temperature stabilizing.

The amount of water used by a plant is affected by various anatomical physiological and environmental factors. Some of these are size, number and location of stomata, size of root system, conductivity of tissue, opening and closing of stomata, diffusion pressure deficit, temperature, air movement, sunshine and amount and availability of water in the soil.

High rates of evapotranspiration, low soil moisture storage and variable distribution of rainfall make the supply of water to plants in Florida a "feast and famine" affair. Most of our research in Florida has been directed toward determining the amount of water needed by plants and toward supplying this need. Even though the average annual rainfall at various points in Florida averages 50 to 65 inches per year, nearly 20 percent of the crop land in Florida is irrigated. More information is needed on basic plant-water relationships in view of our rapidly diminishing water reserves.

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Fertilizer Placement Studies On Farm Crops[1]

W. K. ROBERTSON AND C. E. HUTTON[2]

INTRODUCTION

The effectiveness of fertilizer for farm crops can depend on how it is placed. It may be broadcast on the surface and disked in or it may be placed in bands along the row. Generally, broadcast applications are preferred for small grains and other drilled crops because root systems are distributed through most of the soil. For corn, peanuts, soybeans, and other row crops band placement is preferred since it is usually conceded that the rate of phosphorus fixation is less than for broadcast placement, and the root systems of row crops are confined to a smaller volume of soil at least during the first part of the growing season.

When fertilizer is banded, it is usually placed about 2" to the side and 1" below the row. Lime is usually broadcast on the surface, and then disked into the top six inches. Phosphorus and lime do not move down in most soils. They accumulate in the plow depth area and the soil beneath remains deficient in these materials, thus limiting the extent of the root system and consequently, the moisture supply. In some soils, plow soles

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nd organic hardpans are additional factors which may limit root develop-ent. To rectify these conditions, experiments were initiated to compare lacement of fertilizer and/or lime in the subsoil with surface application s far as root distribution and crops yields were concerned. The effect of ubsoiling alone was also studied.

REVIEW OF PUBLISHED DATA

Subsoiling and deep placement experiments have been conducted for our years in Florida. For the first two years the experiments were quali-ative. They were designed to compare the effect of fertilizer and/or lime laced 14" deep with subsoiling alone and equivalent amount of fertilizer nd lime on the surface. The experiments were conducted on seven dif-erent soil types representing much of the crop land in north Florida. The data from these tests have been reported (2). The following con-lusions were made. On the light sands in north central Florida, place-ent in the surface was as good as in the subsoil. On flatwood soils, near ainesville, subsoiling alone, placement of fertilizer and/or lime 14" deep ncreased corn yields when rainfall was normally distributed. When rain-all was heavy during early growth, placement of fertilizer and lime on he surface was as good as placement in the subsoil, and subsoiling alone as of little value. On the heavier soils in west Florida, often better rowth was obtained for deep placement as compared to surface fertiliza-ion in early growth, but by tasselling time the advantage was lost and here was no significant yield difference. This was probably because mois-ure and not fertilizer was the most limiting factor. High rates of fertilizer ere used to test the residual effect of subsoiling and deep placed fertilizer he following year. Yield differences were significant in one out of six xperiments. It appeared from this that the plow sole may re-develop luring the interval between crops.

In the previous study analyses of corn leaves at tasselling time and isual root inspection showed that corn was feeding in the fertilizer bands 4" deep. A further one-year study with corn also reported (3) involved he placement of P^{32} tagged superphosphate 2", 8", 14" and 20" deep in hosphorus deficient Norfolk loamy fine sand and Red Bay fine sandy loam (1). In these studies it was found that the shallow placements had the ighest percentage recovery of fertilizer phosphorus early in the season, ut by tasselling time the deep placement was as available as the shallow lacement. Yields generally increased progressively with depth of place-ent.

CURRENT STUDIES

The study using P^{32} was repeated a second year on Red Bay fine sandy oam, using corn, soybeans, and peanuts as indicator crops. The rate of agged phosphorus was 35 lbs. per acre P_2O_5. The soil was high in residual ertilizer phosphorus. Placement was made with the same specially built quipment (4). The plants were sampled three times at approximately iweekly intervals. The last sampling date was at tasselling time for corn, lossoming time for soybeans, and early maturity for peanuts. The per-ent phosphorus in the plant and the percentage recovery of fertilizer hosphorus were calculated.

Yield and percent recovery of fertilizer phosphorus data for corn, peanuts, and soybeans are shown in Tables 1, 2, and 3 respectively. The percent recovery of fertilizer phosphorus data indicated that the 2″ placement was best at the first sampling date, but by the last sampling date roots were feeding in the deep band and phosphorus recovery was almost as high from it as from the 2″ placement. This was true for the three crops. Placement of fertilizer did not have a significant effect on the percent phosphorus in the plant for either crop at any sampling date, probably because the rate of application, 35 pounds per acre of P_2O_5, was low in comparison with the residual soil phosphorus so that the uptake from the fertilizer in comparison to the soil was small and sampling error masked differences.

The growth of the three crops was poorer from the first stages of growth on the treated plots than the check. The difference was greater with increasing depth of placement or subsoiling. During the period of most rapid growth, height differences were as much as 8″ for corn, 6″ for soybeans, and 4″ for peanuts.

Growth differences were reflected in yields of the three crops probability for peanuts and soybeans and approached significance for corn. Placement experiments have been carried out 4 years on the Red Bay fine sandy loam, and this experiment was the only one that indicated an adverse effect from subsoiling. Stand counts were made on corn, and although there were somewhat fewer plants on the subsoiled treatments, the difference between them and the check was not significant at the 5% level of probability. It was suspected that the subsoiling affected the physical conditions of the soil so that the soil dried out just prior to planting and the rainfall distribution was such that after planting growth was retarded. Phosphorus placement did not seem to be a factor since corn yields for subsoiling 20″ deep only were not different from phosphorus placed 20″ deep. Peanut and soybean yields were practically the same for the treatment where phosphorus was placed 14″ deep and the one where phosphorus was placed 2″ deep and subsoiling was 14″ deep.

The effect of subsoiling and placed fertilizer or lime on root distribution was studied. Corn was used as the indication crop on Red Bay fine sandy loam. The treatments are listed in Table 4. Dolomitic lime was applied at the rate of 1 ton per acre to treatments 1, 3, and 4. The fertilizer applied in treatment 3 and 4 was 10-10-10 per acre and the amount

TABLE 1.—CORN YIELDS AND PERCENT RECOVERY OF FERTILIZER PHOSPHORUS FROM RED BAY FINE SANDY LOAM

No.	Treatment* Placed	Subsoiled	Yield bus./A	% Recovery of fert. P. June 3	June 17
1	2″	2″	89	24	4
2	8″	8″	86	16	2
3	14″	14″	82	12	2
4	20″	20″	74	6	4
5	8 & 14″	14″	79	8	12
6	Subsoiled only	20″	75		
7	Check		85		
	L. S. D. 5%		N.S		

*Phosphorus tagged with P^{32} was placed at the rate of 35 lbs /A P_2O_5

TABLE 2.—PEANUT YIELDS AND PERCENT RECOVERY OF FERTILIZER PHOSPHORUS FROM RED BAY FINE SANDY LOAM

No.	Treatment* Placed	Subsoiled	Yield lbs./A	% Recovery of Fert. P. June 3	June 17	July 1
1	2	14	1240	11	9	6
2	8	8	1560	10	10	7
3	14	14	1290	7	7	3
4	20	20	1170	5	6	4
5	Check		1450			
	L. S. D. 5%		370	4	N.S.	3
	1%		N.S.	N.S.		4

*Phosphorus tagged with P^{32} was placed at the rate of 35 pounds per acre P_2O_5.

applied in treatment 2 was 100-100-100. In addition all plots received 300 pounds per acre of 4-12-12 at planting and 150 pounds per acre of ammonium nitrate as a side dressing when the corn was knee high.

Just before tasselling time a corn plant representing each plot was cut off at ground level and an excavation about 3 feet wide and 20 inches deep, was made at right angles to the corn row and touching the stalk. This exposed a cross section of the root system. Figure 1 shows the excavation for a plant from treatment 1. A ¾" plywood board, approximately 32" x 17" in size, with 10 d nails driven through on 1" centers and backed with an additional sheet of plywood to hold the nails in place was pressed and then driven into the side of the pit containing the exposed roots. The nails were completely covered with soil throughout the area of the board (Figure 2). A shovel was used to break out approximately a 6" layer of soil. A hand reaping sickle was then used to slice off the soil level with the points of the nails (Figure 3). The soil was washed away from the roots by gentle spraying with a garden hose leaving behind the corn roots adhering to the nails (Figure 4). The roots were removed from the board in 0-6, 6-12, and 12-18 inch sections, dried and weighed. The data are shown in Table 3 along with the corn yield data.

The yield data in Table 3 were significantly different at the 5% level of probability. Fertilizer in the subsoil improved yields over the check, subsoiling only, and the lime placement treatments. The treatments did

TABLE 3.—SOYBEANS YIELDS AND PERCENT RECOVERY OF FERTILIZER PHOSPHORUS FROM RED BAY FINE SANDY LOAM

No.	Treatment* Placed	Subsoiled	Yield Bu./A	% Recovery of Fert. P. June 3	June 17	July 1
1	2	14	17	17	7	6
2	8	8	30	18	6	7
3	14	14	19	11	5	5
4	20	20	17	4	4	4
5	Check		33	---	---	
	L. S. D. 5%		12	6.0	3.0	N.S.
	L. S. D. 1%			8.0	N.S.	

*Phosphorus tagged with P^{32} was placed at the rate of 35 lbs/A P_2O_5.

TABLE 4.—EFFECT OF FERTILIZER AND LIME PLACEMENT ON CORN YIELDS AND ROOT DISTRIBUTION

No.	Treatment* Material**	Placed	Yield bus./A	Oven dry weight of roots in gms 0-6"	6-12"	12-18"	6-18"
1	Lime	14"	75	8.65	0.46	0.51	0.97
2	Fertilizer	14"	94	8.85	0.84	0.52	1.36
3	Fertilizer & Lime	14"	88	7.40	0.60	0.66	1.26
4	Fertilizer & Lime	8 & 14"	84	7.35	0.86	0.68	1.54
5	Subsoiled only	14"	73	7.82	0.60	0.57	1.17
6	Check		71	7.60	0.33	0.24	0.57
	L. S. D. 5%		16	N.S.	0.32	0.23	.44
	1%		N.S.		N.S.	N.S.	.61

*All plots had a uniform application of 300 pounds per acre of 4-12-12 at planting and 150 pounds per acre of ammonium nitrate as a side dressing when the corn was knee high.

**The rate per acre of lime was 1 ton per acre. Treatment 2 received 100-100-100 fertilizer. Treatment 3 and 4, 40-40-40.

not affect the amount of roots in the 0-6" layer of the section sampled, but it did at the 6-12" and 12-18" depths. Differences were somewhat inconsistent at the 6 to 12" and 12-18 depths so the values were added and reanalyzed. Subsoiling and deep placement increased the amount of roots in the 6-18" section above the check. The highest value was obtained when

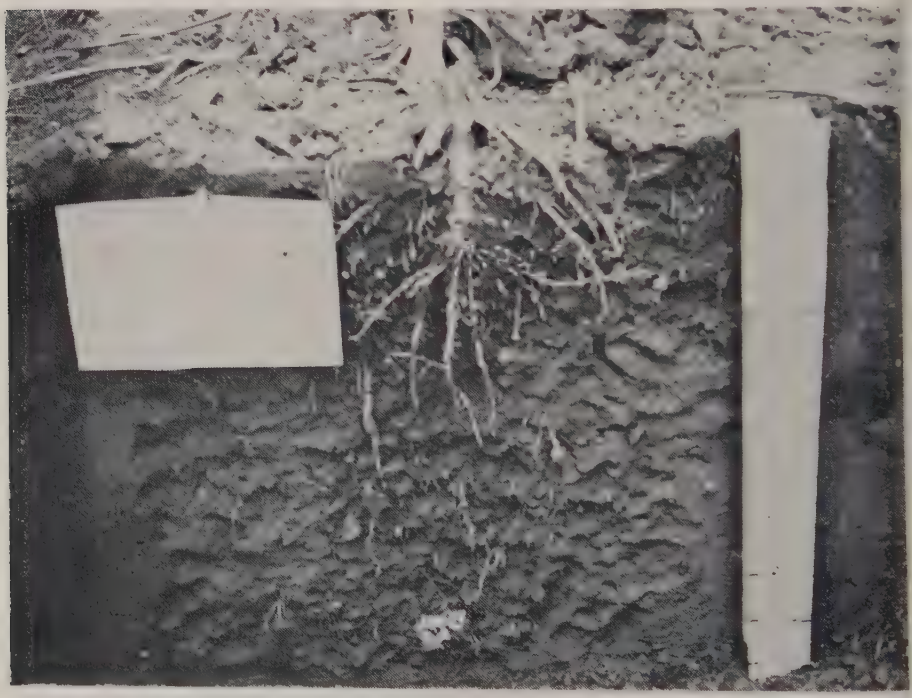

Figure 1.—Excavation made at right angles to the corn row cutting the root system in two. Cross sections of the lime band in lower center.

Figure 2.—Hammering the board in place

Figure 3.—The soil was washed away leaving roots adhering to the nails.

placement was at 8 and 14", indicating that a vertical band might be the better method of application. Lime placed 14 inches deep did not improve root development over subsoiling alone, but subsoiling improved root development in the 6-18" layer of the profile above the check.

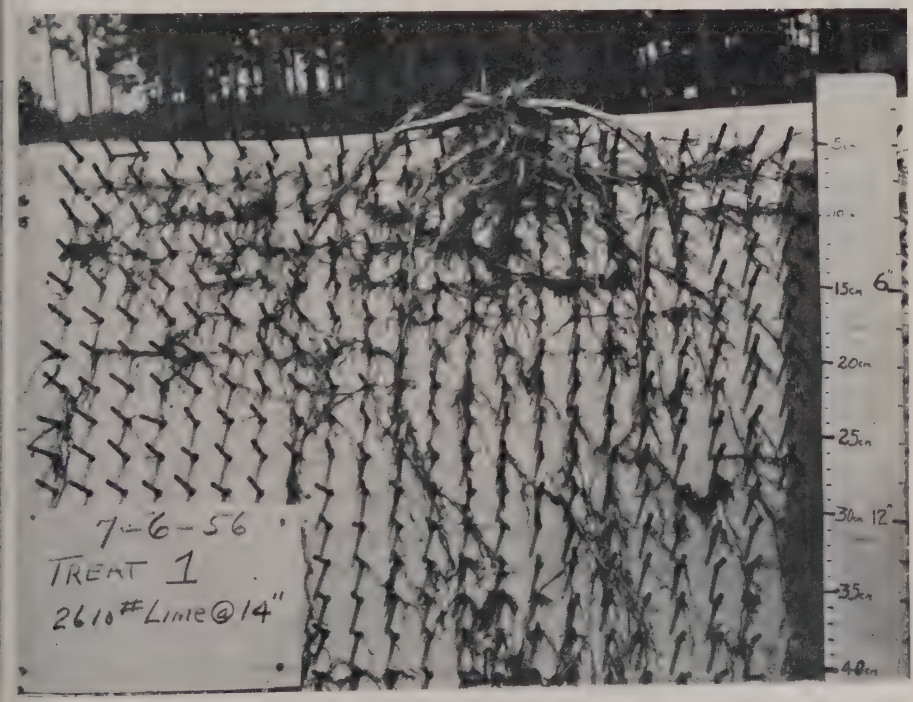

Figure 4.—Showing distribution of the roots as affected by lime placement.

SUMMARY AND CONCLUSION

Subsoiling and placement of fertilizer and lime in the subsoil as a means of improving corn yields in Florida may be important on soils having plow soles or hardpans under certain rainfall distribution. When rainfall is light following planting, roots may penetrate deeper, where the soil is subsoiled and develop more proficiently in the bands of deep placed fertilizer or lime. The deeper root system enables the plant to withstand longer periods of moisture stress than the shallow rooted plants. During some seasons this may result in larger yields. When rainfall is adequate to excessive following planting, roots do not penetrate the subsoil because of the high water tables and hence the plants show no benefit from these practices.

There was usually no residual effect of deep placed fertilizer and lime even when extremely high rates were applied. It appeared as if the plow sole or hard pan reformed during the interval between cropping.

One year in four a detrimental effect in growth and yield for corn, peanuts, and soybeans was obtained. This was attributed to excessive drying of the soil following subsoiling.

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Plant Populations And Nitrogen Fertilization For Field Corn in North Florida[1]

E. S. Horner, D. E. McCloud, and I. M. Wofford[2]

Field corn is becoming more and more important as a cash crop in north Florida. Better cultural practices and the availability of improved hybrids and mechanical harvesting equipment, especially picker-shellers, have to a large extent made this possible. Corn yields can now be increased to a profitable level in this area, and new harvesting and drying methods enable the farmer to market his crop before the seasonal price drop occurs.

Concurrently, farmers have become more interested in intensive culture of field corn. County corn-growing contests have demonstrated that yields surpassing 100 bushels per acre are not at all impossible. However, the cultural methods followed to obtain such high yields have been arrived at somewhat arbitrarily. For this reason, an experiment was designed primarily to evaluate the interaction of nitrogen fertilization and plant populations (spacings) at high levels when other fertilizer elements and water were not limiting. Incidental to testing nitrogen and population levels was the evaluation of irrigation levels, dates of planting, and two varieties of hybrid corn.

LITERATURE REVIEW

Work in Florida on spacing and nitrogen fertilization of field corn prior to 1956 was reviewed in some detail by Wofford *et al* (9). In general, it was found in north Florida that populations in excess of about 6,000 plants per acre and applications of more than 60 pounds of nitrogen per acre did not produce much additional grain yield (2, 8).

Since 1956, however, research done on the Main Station farm at Gainesville indicates that levels higher than those mentioned above can be used profitably. Wofford, *et al* (9) presented a preliminary report on the non-irrigated phase of the present experiment for the year 1956. They obtained no increase in yield when nitrogen application was increased from 100 to 220 pounds per acre at a population of 7,000 plants, but at 11,000 plants per acre on identical increase in nitrogen (from 100 to 220 pounds) raised the yield from 69 to 84 bushels per acre. Similar interactions of nitrogen rates and populations have been noted in other states by Krantz (3), Long (4) and Thomas (7). Prine, *et al* (6) reported increased production of grain and forage up to 17,000 plants per acre, the highest population rate used. However, they found that nitrogen rates over 100 pounds per acre (plus approximately 60 pounds from a lupine cover crop) did not increase grain or silage yields.

METHODS

The experiment was conducted in 1956 and 1957 at the Main Station farm unit, Gainesville, Florida, on Arredondo loamy fine sand. Eight levels each of nitrogen fertilization and plant population were tested, in sets of five levels at four planned irrigation frequencies, as shown in Table

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1. Nitrogen was applied in increments of 60 pounds per acre, starting at 40 pounds; and populations were increased by increments of 2,000 plants per acre, starting at 5,000. Where no irrigation was planned (WO level), rates were 40 to 280 pounds of nitrogen and 5,000 to 13,000 plants per acre (five levels each). Where irrigation was planned at a 1-inch water deficit (W1 level), rates were 220 to 460 pounds of nitrogen and 11,000 to 19,000 plants per acre. At the intermediate irrigation frequencies (W4 and W2 levels), rates between the extremes just listed were used (Table 1). Because different sets of nitrogen and population rates were tested at the different planned irrigation levels (frequencies), interpretation of the results with respect to benefits from irrigation must be made with this in mind.

A partial replication design as proposed by Box (1) was used in order to reduce the number of treatment combinations required, and still allow fitting of response surfaces. The main plots for irrigation levels were 60' x 180' in size. These were split into three dates of planting: March 1, March 21 and April 15. The nine combinations of nitrogen and population (Table 1) were randomized within each date of planting subplot on plots six rows wide and 20 feet long. Rows were 38 inches apart. Each of the six-row combination plots were split into two varieties, Dixie 18 and

TABLE 1.—TREATMENTS (COMBINATIONS OF NITROGEN FERTILIZATION AND PLANT POPULATION) TESTED AT THE INDICATED PLANNED IRRIGATION LEVELS.*

460						W1		
400					W2 W1		W1	
340				W4 W2 W1		W2 W1		W1
280			W4 W2 WO		W4 W2 W1		W2 W1	
220		W4 WO		W4 W2 WO		W4 W2 W1		
160	WO		W4 WO		W4 W2 WO			
100		WO		W4 WO				
40			WO					
	5	7	9	11	13	15	17	19

Thousands of plants per acre

*WO—no irrigation
W4—irrigation planned at 4" deficit (water budget method)
W2—irrigation planned at 2" deficit (water budget method)
W1—irrigation planned at 1" deficit (water budget method)

Florida 200, and only the four center rows were harvested (two rows of each variety). The experiment was replicated three times, and the same land was used each year.

Fertilization other than nitrogen application was as follows each year:

Irrigation level	0-10-20 broadcast	Minor element mixture*
W0	1400 lbs./acre	300 lbs./acre in row
W4	1700 lbs./acre	300 lbs./acre in row
W2	2000 lbs./acre	300 lbs./acre in row
W1	2300 lbs./acre	300 lbs./acre in row

*Minor element mixture consisted of 1,000 lbs. 0-10-20 mixed with 45 lbs. of FN-501 (fritted minors) and 6 lbs. $ZNSO_4$. FN-501 contains 12.3% Fe, 4.6% Mn. 4% Zn, 2.0%Cu, 2.0% B, and 0.13% Mo.

(The different rates of 0-10-20 used at the different irrigation levels apparently had little or no effect on yields.) Lime was applied at the rate of 1 ton of dolomite per acre prior to planting the 1956 crop. A crop of lupines that supplied approximately 60 lbs. per acre of nitrogen was plowed under each year about one month before the crop was planted. One fourth of the nitrogen (ammonium nitrate) was applied at planting, and the remaining nitrogen was applied as follows: ¼ at knee-high stage, ¼ at chest high and ¼ at pre-tasselling.

The seed was hand-planted two seed per hill and later thinned to one plant per hill in an attempt to obtain perfect stands. Damage from wind, insects and birds caused some stand variation; so yields were adjusted to uniform stands and 15 percent moisture.

In 1956 irrigation water needs were determined by the water budget method using daily estimated potential evapotranspiration values as determined by the formula of McCloud (5), supplemented by drying soil samples in an oven to determine moisture contents. Irrigation water in sufficient amounts to bring the soil back to field capacity was applied when available soil moisture was removed to a deficit of: 1 inch for irrigation level W1, 2 inches for level W2 and 4 inches for level W4. Irrigation level W0 received only normal rainfall except for a light watering at planting which all plots received. Excluding the irrigation immediately after planting, the following applications in inches were made in 1956:

Date	Irrigation level W1	W2	W4
May 18	.88	-----	-----
May 23	-----	2.25	-----
May 24	1.23	-----	-----
June 4	1.25	-----	-----
June 5	-----	-----	2.00
June 6	-----	-----	1.00
June 7	-----	-----	1.00
June 8	1.00	2.00	-----
June 15	1.00	-----	-----

During this period significant amounts of rainfall were recorded on May 25 (1.04 in.), May 26 (0.39 in.) and June 10 (2.73 in.). After June 15 there was no extended period without rainfall and irrigation was stopped.

Rainfall during the growing season in 1957 was above normal and well distributed; so no irrigation was done.

RESULTS AND DISCUSSION

Combined analyses. In both years there were highly significant differences among irrigation levels, dates of planting, combinations of nitrogen and spacing, and varieties (table 2). However, the irrigation level sums of squares are unadjusted for combinations (each level has a different set of combinations). Only the first two dates of planting were analyzed in the 1957 data because high winds almost completely lodged the third date, making it very difficult to keep rows separate at harvest.

The second order interaction variety x date x irrigation was significant in 1957 but not in 1956. However, this does not appear to be of importance in view of the fact that none of the first order interactions were significantly large either year.

In order to have comparable data, only the first two dates of planting were used in combining the two years' results at each planned irrigation level. Since there was no significant interaction involving dates and varieties, and the primary interest is in nitrogen and plant population levels, the analyses combining years were made on the basis of whole plots so that dates and varieties were not variables. The separate analyses for the four planned irrigation levels showed highly significant differences among combinations of nitrogen and population at each level (table 3). Interaction of treatment combination and years was not significant at any level.

TABLE 2.—ANALYSIS OF VARIANCE (PLANNED IRRIGATION LEVELS COMBINED).

Source	1956		1957	
	d.f.	mean squares	d.f.	mean squares
Replications	2	9,334	3	15,608*
Irrigation[1]	3	26,172**	2	12,650
Error (a)	6	2,300	6	1,808
Dates	2	105,709**	1	14,294**
Dates x Irrigation[1]	6	981	3	180
Error (b)	16	874	8	660
Combinations[2]	32	1,214**	32	1,007**
Comb.[2] x Dates	64	194	32	122
Error (c)	192	162	128	105
Varieties	1	14,602**	1	1,312**
Var. x Irrigation[1]	3	75	3	127
Var. x Dates	2	90	1	104
Var. x Dates x Irrigation[1]	6	54	3	282*
Var. x Comb.[2]	32	89	32	52
Var. x Comb.[2] x Dates	64	81	32	49
Error (d)	216	94	144	68

[1]Irrigation levels and combinations are confounded.
[2]Sums of squares obtained by pooling.

TABLE 3.—ANALYSIS OF VARIANCE FOR THE RESPONSE SURFACE OF THE 1956 AND 1957 DATA COMBINED AT EACH IRRIGATION LEVEL.

Source of variation	d.f.	Mean squares at each irrigation level			
		W0	W4	W2	W1
Replications in Years	4	3761	9367	3829	968
Years	1	2646	3700	5849	6369
Combinations	8	3009**	1658**	1561**	1416**
Linear Nitrogen	1	1615**	1418**	38	317
Linear Population	1	21252**	10379**	11456**	6521**
Linear N x Lin. Pop.	1	408	59	6	150
Curvature	2	230	486*	133	1459**
Quad. Nitrogen	1	460	589*	17	658*
Quad. Population	1	169	911*	105	2853**
Residual	3	113	48	222	474
Combinations x Years	8	222	53	176	127
Error	32	111	146	137	171

The irrigation levels were not combined in the two-year analyses because they are confounded with combinations.

Irrigation in 1956: It is possible to assess the benefit of applying supplemental irrigation in the amounts previously shown by comparing treatments common to the different irrigation levels. These comparisons show that there was no significant increase in grain yield due to irrigation (table 4), even though there were periods of drought when the corn leaves rolled rather severely. The failure of irrigation to be of greater benefit no doubt was due largely to the fact that rather heavy rains (1.43 inches during May 25-26 and 2.73 inches on June 10) occurred within one to three days after much of the irrigation water had been applied. After June 10 there was good rainfall distribution and little need for irrigation.

Since there was no significant yield increase from irrigation in 1956 and since the years x combinations interaction was not large at any irrigation level, the difference in treatment between the 1956 and 1957 plots is ignored in combining the two years data.

TABLE 4—COMPARISONS OF YIELDS AT FOUR IRRIGATION LEVELS IN 1956.

Comparison	Number of treatments averaged	Average bushels per acre for comparable treatments.				Difference[2]
		W0	W4	W2	W1	
W0[1]-W4	6	81.7	86.1	-----	-----	4.4
W0-W2	3	89.2	-----	97.1	-----	7.9
W4-W2	6	-----	93.5	99.9	-----	6.4
W4-W1	3	-----	96.0	-----	99.9	3.9
W2-W1	6	-----	-----	105.9	105.9	0.0

[1]W0—no irrigation
W4—one irrigation at a 4-inch deficit (total of 4.00 inches)
W2—two irrigations at a 2-inch deficit (total of 4.25 inches)
W1—five irrigations at a 1-inch deficit (total 5.36 inches)
[2]None of the differences were significant statistically.

TABLE 5.—REGRESSION COEFFICIENTS OF YIELD ON NITROGEN AND ON POPULATION AT THE DIFFERENT IRRIGATION LEVELS.

Factor	Coefficient	W0	W4	W2	W1
Linear Nitrogen	b_1	2.37**	2.22**	— .365	1.05
Linear Population	b_2	8.59**	6.00**	6.31**	4.76**
Linear N. x Pop.	b_{12}	2.063	—0.781	—0.240	1.25
Quadratic Nitrogen	b_{11}	—0.408	—0.462	0.77	—0.488
Quadratic Population	b_{22}	—0.247	—0.574*	—0.194	—1.016

Nitrogen levels. The linear regression of yield on nitrogen fertilization was highly significant at the W0 and W4 irrigation levels, where nitrogen rates ranged from 40 to 280 and 100 to 340 pounds per acre, respectively (Table 3). At the W2 and W1 levels, where the lowest N rates were 160 and 220 pounds per acre, respectively, this linear regression was not significant. The curvilinear regression was significant at the 5 percent level in the W4 and W1 irrigation levels, but not at the W0 and W2 levels (see Table 5 for regression coefficients).

These results with respect to nitrogen levels indicate that there was little response to added increments beyond the 160 pound level. This is illustrated graphically in Figure 1, where regression curves for 11,000 and 15,000 plants per acre are plotted.

Actual yields of grain for the two years (dates I and II) are given in

TABLE 6.—SUMMARY OF YIELDS AND OTHER DATA FOR THE FIRST TWO DATES OF PLANTING (TWO-YEAR AVERAGE).

Treatment combination		Bushels per acre					Per-cent erect plants	Ear wt. lbs.	No. of ears per plant	Ear height, feet
Plants per acre	Lbs. N per acre	Irrigation level								
		W0	W4	W2	W1	Ave.				
5000	160	55.1				55.1	94	0.46	1.77	5.0
7000	100	67.9				67.9	86	0.43	1.65	4.8
7000	220	68.2	69.9			69.1	83	0.43	1.68	4.8
9000	40	66.4				66.4	87	0.40	1.37	4.7
9000	160	74.7	76.2			75.4	83	0.43	1.44	5.1
9000	280	76.2	84.9	82.4		81.2	84	0.45	1.45	5.1
11000	100	79.0	81.0			80.0	83	0.42	1.27	5.2
11000	220	87.6	90.5	94.8		91.0	81	0.44	1.39	5.3
11000	340		87.2	91.8	84.9	88.0	78	0.44	1.37	5.6
13000	160	91.3	88.1	99.3		92.9	77	0.42	1.23	5.3
13000	280		93.7	99.7	99.6	97.7	74	0.44	1.25	5.5
13000	400			100.5	101.3	100.9	75	0.44	1.29	5.4
15000	220		95.6	104.5	102.2	100.8	73	0.42	1.16	5.5
15000	340			100.6	111.0	105.8	71	0.44	1.16	5.7
15000	460				104.3	104.3	67	0.44	1.13	5.7
17000	280			111.0	101.6	106.3	66	0.42	1.12	5.7
17000	400				108.2	108.2	64	0.42	1.14	5.7
19000	340				108.9	108.9	64	0.42	1.01	5.8

Table 6. These also show, at any given population, only a very limited response to added nitrogen at levels above 160 to 220 pounds per acre. For example, at 15,000 plants per acre, an increase of N from 220 to 340 produced only five bushels additional grain. At lower populations there was less response to increased nitrogen than at the higher populations, as would be expected. This is seen at 7,000 plants per acre, where an increase from 100 to 220 pounds of nitrogen resulted in practically no increase in yield.

Population levels. There was a much larger response to increased numbers of plants per acre over the range used than was the case for nitrogen. The mean squares for linear regression of yield on population was highly significant at all irrigation levels (Table 3), and the linear regression coefficients were relatively large (Table 5). However, at the W1 irrigation level, where high nitrogen and population rates were used, the curvilinear regression mean square was highly significant. This indicates that the re-

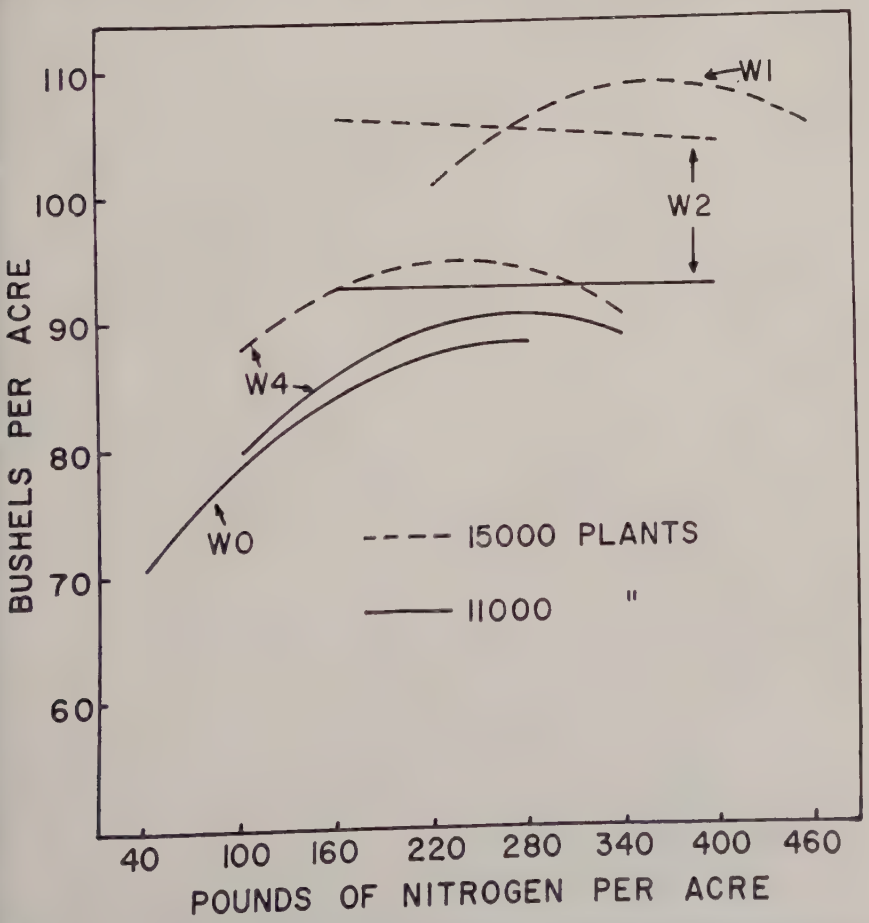

Figure 1.—Regressions of yield on nitrogen level at 11,000 and 15,000 plants per acre within different irrigation levels, 1956-1957.

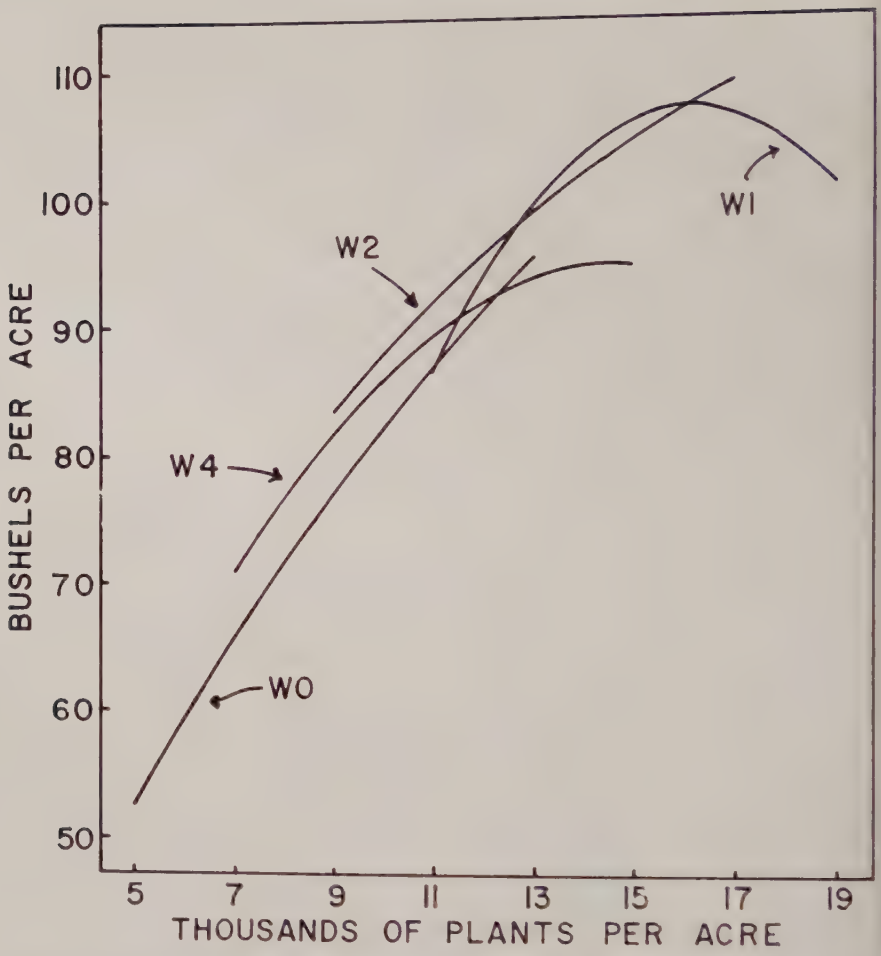

Figure 2. Regressions of yield on population level at 280 pounds of nitrogen per acre within each irrigation level, 1956-1957.

sponse to higher populations was leveling off in this range (11,000 to 19,000 plants). This is illustrated in figure 2 for the 280 pound nitrogen level. There is good agreement among the response surfaces calculated from the different irrigation level data in the overlapping areas.

Inspection of the actual yields (Table 6) also shows a leveling off trend at the higher population levels. At 280 pounds of nitrogen, for example, yields were 81, 98 and 106 bushels per acre for the 9, 13 and 17 thousand populations, respectively. At 340 pounds of nitrogen, yields were 88, 106 and 109 bushels at 11, 15 and 19 thousand plants.

Point of optimum response. It is of interest to calculate the optimum combination of nitrogen and spacing. The data from the W1 irrigation level permits this because in it definite leveling-off responses were found both for nitrogen and for population. Equations have been derived by Box (1) for this purpose as follows:

$$\text{Optimum Nitrogen level} = \frac{(b_1/b_{12} - b_2/6b_{22})}{(b_{21}/6b_{22} - 6b_{11}/b_{12})} \times 60 + 340 = 386 \text{ lbs.}$$

$$\text{Optimum Population level} = \frac{(b_2/b_{12} - b_1/6b_{11})}{(b_{12}/6b_{11} - 6b_{22}/b_{12})} \times 2000 + 15000 = 16{,}634 \text{ Plants}$$

These calculations show that, based on the W1 level data only, the maximum yield would be obtained at 16,634 plants and 386 pounds of nitrogen per acre. This is the highest point on the yield-response curve.

Date of planting. As pointed out earlier, there were highly significant differences in yield among planting dates both in 1956 and 1957. Actual dates and yields per acre in 1956 were March 6, 107.2 bu.; March 26, 81.7 bu.; and April 18, 63.1 bu. In 1957 they were February 28, 91.2 bu. and March 21, 79.7 bu. The lower yields obtained from late planting probably were due in part to heavier infestations of ear worms late in the season. Leaf blight incidence is usually higher late in the season also. It has been observed in other work that April plantings in the Gainesville area do very well if they are well isolated from earlier plantings.

Other characters. Data were also obtained on lodging, ear weight, number of ears per plant and ear height (Table 6). The most striking effect of the high levels of nitrogen and population was on lodging (figure 3). At the low levels there was relatively little lodging, but at 19,000 plants and 340 pounds of N only 64 percent of the plants remained erect at harvest. There was a tendency for more stalk breakage in the first date of planting because stalk rot was further advanced at harvest than at the later dates. An exception to this occurred in 1957 when a high wind in September severely lodged the April 15 date of planting, but did not affect the two earlier dates to a large extent. The failure of this late corn to withstand the wind very likely was due to the fact that late corn grows appreciably taller than early corn. Average ear heights for the three dates of planting were approximately 5.0, 5.5 and 6.5 feet for March 1, March 21 and April 15, respectively.

Average ear weight in pounds ranged from 0.42 to 0.46 for the various combinations of nitrogen and population, indicating that this character was influenced to only a small degree by variations in treatment (Table 6). In contrast, number of ears per plant varied from 1.01 at the 19,000 population level to 1.77 at the 5,000 level, and average ear height ranged from 4.8 feet at 7,000 plants to 5.8 feet at 19,000 plants. An increase in nitrogen rate at a given population resulted in a slight increase in lodging, number of ears per plant, ear weight and ear height (Table 6).

CONCLUSIONS

These data indicate that maximum yields of grain, under the conditions of this experiment, would be obtained with nitrogen applications of about 400 pounds per acre and populations of about 17,000 to 19,000 plants per acre. There are several factors, such as limited amounts of light and carbon dioxide, which may be responsible for the leveling-off trend of yields as population rates were increased. Also, other hybrids may be found that are not affected too adversely by close spacings as Dixie 18 and Florida 200. These hybrids were selected at relatively low populations

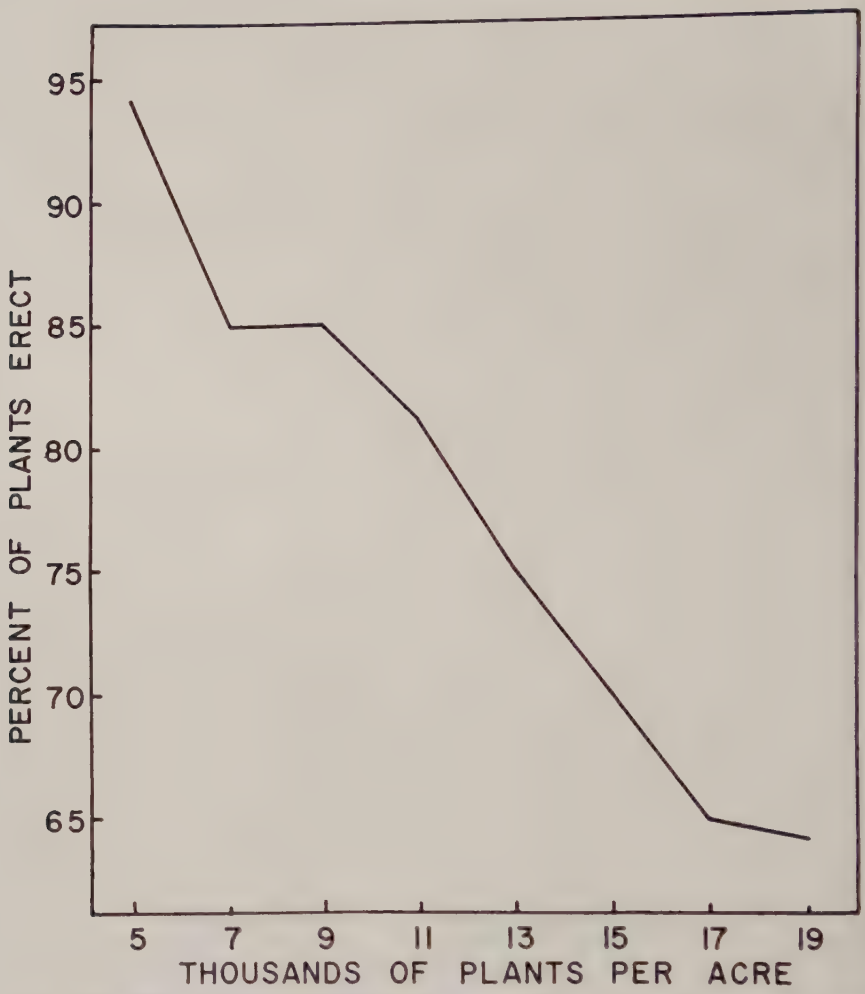

Figure 3. Effect of plant populations on percent of plants erect at harvest, average of all nitrogen rates in 1956 and 1957.

(6,000 to 8,000 plants per acre), and would not be expected to be particularly well adapted to very heavy planting rates.

From the farmer's point of view, the economic return from increasing nitrogen and plant population rates must be considered. Responses to added increments of nitrogen were not large enough to be significant statistically at rates above about 160 to 220 pounds per acre (Fig. 1). It is possible to estimate from the regression curves the point at which an increase in nitrogen fertilization would not be profitable. Assuming values of $1 per bushel of corn and 12¢ per pound of nitrogen, this estimate is 100 pounds and 130 pounds, respectively, for 9,000 and 11,000 plants per acre based on the W0 series of plots (including 60 pounds furnished by the lupine crop). Data from the W4 series indicate that about 130 pounds of nitrogen is the maximum amount that would be profitable at popula-

tions from 9,000 to 15,000 plants per acre. Nitrogen rates used in the W-2 and W1 series were too high to be useful in making these estimates.

Assuming that additions of nitrogen above about 130 pounds per acre would not be profitable, the question of what would be the most profitable population rate remains. This is more difficult to estimate because lodging was much more closely correlated with population rates than with nitrogen rates. However, it is evident that at the higher populations used in this experiment the possible loss from stalk breakage would offset the higher yields obtained. For example, at 13,000 and 17,000 plants per acre, respectively, the average yields at comparable nitrogen rates were 99 and 107 bushels and the average percent of erect plants were 74 and 65 (Table 6). In this case the gain from closer planting was almost exactly canceled by the increased amount of lodging. From this and other comparisons (Table 6), it seems fair to conclude that populations above 13,000 plants per acre should not be recommended for general grain production even if irrigation is available.

It should be emphasized that the above conclusions regarding practical levels of nitrogen and populations are based on results obtained on upland soil in north central Florida in years when moisture and fertility did not appear to be limiting factors. On soils that are low in fertility and moisture-holding capacity, it is very likely that lower rates, especially of populations, would be desirable.

During the period covered by this experiment, irrigation would not have been profitable on this particular soil type, which is intermediate with respect to water-holding capacity compared with other upland soils in north Florida. Both Dixie 18 and Florida 200 can stand considerable moisture stress at pollination time and still produce good yields. Very seldom are droughts in the Gainesville area prolonged so long that corn yields are drastically reduced, especially when good fertilization practices are followed.

An early March planting date produced significantly higher grain yields than either late March or mid-April dates. However, this decline in yield is at least partially due to buildup of insects and diseases in the late plantings, as was pointed out earlier. If late plantings in the Gainesville area are well isolated from earlier plantings, they have been observed to produce excellent yields.

SUMMARY

An experiment was conducted at Gainesville in 1956 and 1957 to test the joint effect of irrigation, nitrogen, spacing levels and date of planting on the grain yield of two field corn varieties, Dixie 18 and Florida 200.

Four to five inches of supplemental water during May and early June of 1956 did not increase grain yields significantly.

Early March planting produced significantly higher yields than late March or mid-April planting in both years.

Nitrogen applications heavier than about 200 pounds per acre failed to produce significantly higher yields, even with high populations.

When spacing was varied at high nitrogen rates, grain yields leveled off at about 17,000 plants per acre. However, stalk breakage was much more severe at the higher population and nitrogen levels. It is recommended that farmers do not plant closer than about 13,000 plants per

acre at good fertility levels unless they are entering a corn-growing contest. At 9,000 to 13,000 plants per acre, nitrogen applications in excess of 100 to 130 pounds per acre (including that available from a leguminous cover crop) probably would not prove economical.

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Research On Peanuts During The Last Twenty Years[1]

HENRY C. HARRIS[2]

Experiments on peanuts are being conducted in Florida at the main station and at various branch stations. Since the branch stations have representatives on this program, this paper will be confined to work done during the last twenty years at the main station, dealing especially with plant physiological and soil fertility problems, phases with which the writer has been more concerned. It will be mainly a review, but part of the results have not been published and some explanation as to the nature of those experiments is necessary. At the end of the review, a brief discussion related to future research will be given.

It was easy to get the writer to talk on this subject since to him the peanut is the most interesting of all plants. You probably know that it flowers above ground, and after the flower is fertilized, a "peg" is formed which, because of its geotropic nature, grows invariably downward. Potted plants can be turned upside-down, and the pegs will change direction of growth again turning towards the earth. Elongation of the peg transfers the embryonic seed from an aerial to a subterranean position. The peg develops pressure which enables it to push into the soil about two inches. At that point the geotropic control changes, and the end of the peg orients

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horizontally in which position the seed develops. Even so, the seed will not satisfactorily develop without calcium in contact with the developing fruit, irrespective of how much calcium or other nutrients are in contact with the roots. The whole process is a complex mixture of physics, chemistry and biology, and my reaction is that the development and birth of a child is no more complicated.

The peanut is not only interesting scientifically, but it is a valuable plant. Life seems to be a race against time, and under those conditions, man develops circulatory troubles, and since some varieties of peanuts are high in unsaturated fatty acids, they may become increasingly important in the diet of persons with circulatory troubles. Furthermore, soft pork, which results when hogs are fed peanuts, can be cut readily under modern refrigeration, and since the unsaturated fatty acids of the peanuts are stored in the pork, it may become important in some diets. The nuts are not only high in special types of oils, but they are tasty, high in protein, and in general, nutritious for human beings. In addition, the foliage of peanuts compared favorable in chemical composition (33, 35) to alfalfa hay. It would seem possible to produce a high protein type of animal food by ensiling the foliage and nuts together. Thus, peanuts are excellent food both for human beings and animals, and numerous possibilities exist for the use of peanuts industrially. Since this plant is adapted to the south, it would seem short-sighted, indeed, for people in this area not to conduct intensive research in an effort to make the most of a wonderful plant.

EARLY EXPERIMENTS

Experimental results on peanuts in Florida (32) up to 1940 indicated a modest response to gypsum and fertilization. Close spacing of the plants generally increased yields moderately. Dusting results in Virginia (1, 34) and Georgia (39) had stimulated interest in Florida, and during the early 40's, sulfur and copper-sulfur dust were shown to be beneficial (32).

SULFUR DUSTING EXPERIMENTS

The question arose as to whether sulfur dusting actually increased the nut yields. It was observed that many peanuts, when harvested by the ordinary digging process, shed and were not harvested. It would be necessary to account for the peanuts harvested on the vines as well as for the peanuts not harvested to properly interpret the results. With that in mind in 1944, several sulfur dusting experiments (4) were conducted. The results indicated that the sulfur treatment mainly increased the amount of peanuts retained on the vines, and the total yield of nuts was not materially affected. The sulfur treatment in several cases did increase hay. In another test (30), the effect of sulfur dusting was similar although the results were not entirely consistent. In the latter test, Cryolite and DDT applied to the foliage for insect control appeared to decrease the amount of peanuts shed.

Extensive field experiments (18, 19) were conducted, in cooperation with W. B. Tisdale and A. N. Tissot of the Florida Agricultural Experiment Station, on the station farm, Gainesville, Florida, during 1946. A uniform treatment of 400 pounds per acre of 2-14-12 fertilizer containing the

micronutrients was applied to all plots about two weeks before seeding. The fertilizer was mixed in an area about one foot wide under where the peanut rows were to be. Florida Runner variety was grown. A plot consisted of two rows four feet apart and ten feet long (8′ x 10′). The dusting treatments were randomized in six blocks. A number of treatments were applied, the more important of which are listed in Table 1 together with the yields obtained. These treatments, with the exception of four sulfur dustings and DDT only, all significantly increased hay yields, and the only treatment that failed to increase significantly the harvested peanuts was the four sulfur dustings. The total yield of peanuts was slightly increased by frequent sulfur dustings or by Cryolite treatment. Four standard sulfur dustings had no effect on total yield. The same total amount of sulfur, as used in frequent dustings but mixed in the soil of the pegging area, slightly decreased the total yield of nuts. The sulfur treatments appeared to cause the foliage of the peanuts, during the main part of the growing season, to have a lighter green color. The reason for this was not clear. It was true irrespective of whether the sulfur was mixed in the soil of the pegging area or whether applied as a dust to the foliage. Samples of soil were taken from the pegging areas of all the plots in early August, 1946, and the pH values are given in Table 1. All of the sulfur treatments increased acidity, and the soil application had the most effect. This greater acidity might explain why the sulfur in the pegging zone slightly decreased total yield of nuts. Grades on leafspot damage indicated that frequent sulfur dusting was most effective in controlling the disease, but even soil sulfur in the pegging area seemed to decrease slightly the amount of leaf spot. The best control of insects was a combination of frequent sulfur dustings plus DDT applications at the time danger of insect activity appeared. Thus, it seems that the main effect of sulfur on the yield of peanuts was to improve retention of the fruits on the vines. However, there must have been some nutritional, or other effects, since it caused a difference in the color of the plants, and it slightly increased the total yield of nuts. The beneficial effects of Cryolite or DDT treatments obviously were related to better insect control.

NUTRIENT SOLUTION STUDIES

Burkhart and Collins (12) demonstrated the uptake of lithium by the fruiting organs and reported that calcium in the fruiting medium had a beneficial effect on fruit quality. Their experiments were a resurrection of the ideas of Pettit (36), Van der Wolk (37), and Waldron (38) that the fruiting organs actually absorbed something from the soil. The work of Burkhart and Collins stimulated great activity on the part of North Carolina scientists concerning the importance of calcium in the fruiting zone. The writer knows from personal experience that it was a common practice of North Carolina farmers in the early 20's to apply calcium sulfate to peanuts. They knew of the importance of calcium and lime for this crop but they did not know about the necessity of a certain amount of calcium in contact with the developing fruit.

Meanwhile, and at about the same time, workers in Florida had begun research on the nutrient requirements of both the fruit and root system of peanuts. Root-hair-like formations on the pegs (3) suggested that the fruiting system was involved. It was thought that sand culture would be the best way of establishing the nutrient requirement of this

plant. Thoroughly acid-washed sand was used, and a special culture was devised (10) in which the roots of each plant were completely isolated from the fruiting or pegging zone of the plant. In this way the nutrient solution in the fruiting area could be varied without affecting the solution in the rooting zone and vice versa. Using this manner of experimentation, a series of fundamental experiments were conducted with peanuts concerning nutrients—requirements, movement and effects (2, 3, 10, 15, 16).

Results in 1945 (3, 10) showed that peanuts did not develop fruit when only water was applied to the fruiting zone, even though a complete nutrient treatment was applied to the root system. Furthermore, a deficiency in the rooting zone of any one of the major nutrients greatly decreased both the yield of peanuts and vegetative growth. A low level of the group of micro-nutrients also had a marked detrimental effect on growth and yield of nuts. The deficiency symptoms were striking and were described in the publications. Magnesium deficiency increased leaf-spot susceptibility (10).

Results in 1946 (15) confirmed and expanded the previous work. The deficiency symptoms were described. It was shown that a deficiency of calcium only, in the fruiting zone would prevent satisfactory fruiting. The sulfate ion in the fruiting zone seems to be slightly beneficial. Molybdenum increased vegetative growth. P^{32} and Co^{60} were absorbed by the fruiting system and transferred to other parts of the plant, but there was more P^{32} and Co^{60} in the fruits when these radioactive isotopes were applied to the roots than when the isotopes were applied directly to the fruiting system. These tracer studies indicate that the roots are the main absorption area even though there is some absorption through the fruits. The chemical data for the 1945 experiments indicate the same.

Ca^{45} STUDIES

The reason for the necessity of calcium in the fruiting zone for proper fruit development was not understood. In a classic of tracer experiments (2) this problem was elucidated. Radioactive calcium was applied in some cases to the root system and in other cases to the fruiting system. Plant samples were taken at intervals of time after application, and the Ca^{45} evaluated. The Ca^{45} when applied to the roots moved up through the plant and into the young peg, but after the peg entered the sand, there was little or no further movement into the young fruit. On the other hand, Ca^{45} when applied to the fruiting area, entered the fruit and to some degree moved back into the plant. The results indicate that the movement of calcium from the roots to the fruit is limited, thus explaining why good fruit development is dependent on an external supply of calcium in the fruiting zone.

S^{35} EXPERIMENTS

The effect of sulfur on peanuts continued to be of interest and experiments in 1952 and 1954 compared the absorption and movement of sulfur when applied to the root system versus when applied to the fruiting system. The published results (16) are not accessible to many people so it seems appropriate to outline the nature and summarize the findings

TABLE 1.—MEAN EFFECT IN 1946 OF DUSTING TREATMENTS ON YIELD OF PEANUTS IN POUNDS PER PLOT (8′ x 10′) AND pH OF THE SOIL TWO WEEKS BEFORE HARVEST

Treat. No.	Treatments Superimposed on Uniform Fertilization	pH of Soil[1]	Hay, Lbs.	Harvested Nuts, Lbs.	Total[2] Nuts Lbs.
1	None.	5.6	3.06	.57	3.00
2	250 pounds S per acre mixed in soil of pegging area, applied May 26, 1946.	4.2	3.56	.81	2.66
3	Twelve weekly dustings, beginning May 24, 1946, using total of 250 pounds S per acre.	4.5	4.76	2.09	3.43
4	DDT applied May 28 and August 10, 1946 primarily for thrip and velvetbean caterpillar control.	5.7	3.33	1.02	3.11
5	DDT as in 4 plus 12 S dustings as in 3.	4.5	4.98	2.22	3.50
6	DDT as in 4 plus soil S as in 2.	4.0	4.12	1.18	2.78
7	Four standard S dustings, beginning May 31, 1946, using total of 90 pounds S per acre.	5.0	3.26	.62	3.04
8	Cryolite applied August 10, 1946 primarily for velvetbean caterpillar control.	5.7	3.44	1.39	3.33
	L. S. D. 5%		.39	.22	.28
	L. S. D. 1%		.53	.29	.38

[1]Values for the six replicates were consistent and were averaged.
[2]Values for nuts shed and left in the soil in the harvesting operation can be calculated by subtracting harvested from total nuts.

of the more important 1954 experiment. The test was conducted similarly to the Ca^{45} experiment (2) previously discussed. The cultures were the same kind. The Early Runner variety of peanuts was grown with the root and fruiting zones isolated from each other. The main stem of this variety grows upright, but the branches which develop from it have a prostrate growth habit. Each of the two fruiting pans of a culture contained 60 pounds of washed coarse builder's sand while the four-gallon glazed crock into which the roots grew contained 48 pounds of this sand. Three plants were grown in each culture, and half of the branches of each plant were trained over one fruiting pan while the other half was trained over the other pan. Peanuts, innoculated with legume bacteria, were planted April 8, 1954, and were grown with the No. 2 complete nutrient solution of Hoagland (31) until June 17, 1954, at which time the plants were freely blooming and pegs were developing. Until then only water had been applied to the fruiting area and a complete nutrient solution to the root zone. On the latter date, the roots were flushed with water, and the different nutrient treatments indicated in Table 2 were begun and continued to the end of the experiment. S^{35}, 48 microcuries as sulfate, was applied June 23, 1954, to each pot or 24 microcuries to each of the two pans of a culture as indicated in Table 2. The treatments were replicated three

times in randomized blocks. Eight days after the S^{35} was applied the foliage over the pans on one side of all cultures was harvested. Nineteen days after the radioactivity was applied the other side of each culture, including the upper part of main upright stem, was harvested. Essentially one-half of the plant was harvested each time. Sulfur deficiency in plants growing in sulfur-deficient cultures developed late in the growing period, and even though chemical analyses showed the plant material from these cultures to be much lower in sulfur content, the deficiency had no appreciable effect on the yield of dry material. The average dry weight yields for treatments ranged from 163 to 183 grams for the last harvest. The material of the last harvest was separated into its various parts and assayed for S^{35} using a proportioned counter with P-10 gas. The results are given in Table 2 and 3.

When S^{35} was applied to either the fruiting system or the root system, it entered and from that point moved to all parts of the plant. A much larger amount of S^{35} was absorbed by the roots than the fruiting system. However, since the surface area of the fruiting system seems to be much smaller than that for the roots, the absorption per unit area of surface for fruiting system would seem to be appreciable. A deficiency of sulfur in the rooting area tended to increase the amount of S^{35} absorbed by the fruiting system and the amount moved to other parts of the plant and vice versa. Therefore, it appears that when the nutrient supply of sulfur in the soil is low, the fruiting system may help the plant in obtaining an adequate amount.

Experiments were also conducted dealing with foliar absorption of S^{35} (9, 25). Young plants having from 16 to 20 leaves were used. S^{35}, as sulfate, in solution was put in a dish and the lower leaf of the plant held in the solution. In six days the leaf in contact with the radioactive sulfur was removed, the plant harvested, and S^{35} in the plant assayed. Several plants were utilized in this type of experiment two different years. One leaf absorbed and transferred to other parts of the plant anywhere from 0.5 to 4.25 percent of the applied activity. It, therefore, appears that good coverage of all leaves might result in appreciable foliar absorption.

The collective information shows that peanuts can obtain sulfur through the roots, and fruiting system, or the foliage.

FIELD EXPERIMENTS WITH COPPER

The micro-nutrients were shown to be important for peanuts in tests which involved nutrient solutions in sand culture and which were mentioned previously. Oats grown on certain soils in the field have responded markedly to copper treatment in the fertilizer. (20). Peanuts, when grown on the same soil in glass containers at the greenhouse, developed copper deficience symptoms (21) which were not present when copper was applied to the soil. These results suggested that copper deficiency of peanuts might occur in the areas in the field where it was prevalent for oats. For these reasons several experiments (17) were conducted. Copper in the fertilizer had a pronounced beneficial effect on the yield of Dixie Runner, Alabama Runner and G.F.A. Spanish varieties, and deficiency symptoms were described. The grade of peanuts as measured by the amount of sound and mature nuts or shrivels was improved by the treatment. Furthermore, in some of the tests, previous application of copper had a marked beneficial

TABLE 2.—AVERAGE EFFECT OF POSITION OF S^{35} APPLICATION AND NUTRIENT TREATMENT ON THE SQUARE ROOT OF COUNTS PER MINUTE FOR 0.8 GRAMS OF PLANT MATERIAL FOR THE LAST HARVEST OF EARLY RUNNER PEANUTS

Nutrient Treatment[1]		Leaves				Stems				Pegs Not in Sand	Shelled Peanuts	Total[2]
Roots	Pegs	Upper	Middle	Lower	Upright	Upper	Middle	Lower	Upright			
C	C*	20.6	12.9	8.8	5.7	18.1	16.3	17.2	3.9	17.7	47.8	65.6
—S	C*	41.0	18.0	10.8	7.5	29.8	19.6	12.9	4.7	32.8	62.3	93.8
C*	—S	126.6	102.0	56.4	96.6	86.1	88.6	87.7	80.3	97.1	85.6	292.1
C*	C	114.4	86.9	55.2	93.7	78.9	85.2	78.7	86.8	91.0	88.5	275.6
LSD 5%		17.7	13.0	7.0	12.2	16.9	11.9	17.2	10.1	17.6	25.2	37.0
LSD 1%		26.8	19.6	10.6	18.5	25.6	18.0	26.1	15.4	26.7	38.2	56.0

[1]Different nutrient treatments begun 25 days before last harvest. C is Hoagland's No. 2 complete nutrient solution (31), —S is his sulfur deficient solution, and * is position S^{35} applied nineteen days before last harvest.

[2]Counts for the ten parts were totaled and the square root of that number obtained. Counts were made on pegs in sand and hulls, but were not included because of possible contamination.

TABLE 3.—AVERAGE PERCENTAGE OF TOTAL S^{35} APPLICATION FOUND IN THE LAST HARVEST OF EARLY RUNNER PEANUTS

Treatment[1]		Percentage
Root	Fruit	
C	C*	1.3
—S	C*	3.1
C*	—S	27.3
C*	C	24.8

[1]Explanation of treatments given in Table 2.

esidual effect. A spray, containing a small amount of copper, on the oliage was also effective.

FIELD FERTILIZER EXPERIMENTS

So far there has been no discussion of fertilizer tests dealing with the sual fertilizer elements—nitrogen, phosphorus, and potassium. An appli- ation of 28 pounds of phosphoric acid and 24 pounds of potash per acre n a field test was reported (30) to have given a moderate increase in ut yield. In 1946 a rather elaborate set of fertilizer experiments (19) as conducted in an area of the station farm at Gainesville, Florida, where ttle fertilizer had been applied in recent years. The treatments centered round a 500 pounds per acre treatment of 2-14-12 fertilizer containing all he micro-nutrients compared to no fertilization. The fertilizer was mixed n an area about 15 inches wide under the peanut row before seeding. In ther cases, individual elements were left out of the fertilizer, but it was pplied in the same manner. In still other cases, the treatment was applied efore seeding and was followed by an additional surface application or wo of the same fertilizer during the growing season. Practically all treat- ents increased the amount of foliage produced. No treatment significantly ncreased the amount of nuts harvested on the vines, but every treatment ignificantly increased the total yield of nuts, indicating that fertilization aused the peanuts to shed the fruit and thus not be obtained in the ordi- ary harvesting operation. The 500 pounds rate of 2-14-12, mixed in a wide rea under the peanut rows before seeding, increased total yield of nuts 5 percent. The various combinations indicated that potash was especially mportant in these experiments.

A complex set of experiments, involving 324 field plots of the Dixie Runner variety, were conducted in 1951 and 1952 (5, 6). The soil was Arredondo loamy fine sand, having a pH value of 5.8, and no fertilizer ad been applied in recent years. Dolomitic limestone at 700 pounds per cre was uniformly applied to all plots. The various fertilizers were in all ombinations with cover crops, soil fumigation, and non-fumigation. Methyl romide was applied at one pound per hundred square feet under plastic overs four to six weeks before seeding as the fumigant. Oats, lupine or allow were the cover crops. The fertilizers involved three rates of nitrogen 0, 15 and 30 pounds), two rates of P_2O_5 (0 and 100 pounds) and three ates of K_2O (0, 70 and 140 pounds) per acre in all combinations. Fumi- ation stunted the peanuts during early growth, but they recovered during he latter part of the growing season. This stunting appeared to be related o an effect on nodulation, even though all seed were innoculated with egume bacterium before planting. The fumigated plots gave larger yields harvested on the vines, possibly because of delay in maturity, but the total ield of peanuts was not materially affected by fumigation. None of the ertilizer treatments or cover crops had very much effect on the total yield f peanuts.

GREENHOUSE EXPERIMENTS WITH BLANTON FINE SAND. LEVEL PHASE

With the hope of better control of fertilizer and water relations than an be done under field conditions, tests were conducted at the greenhouse

in 1954 and 1955 (25, 26, 27, 28). Diseases and insects were controlled without the use of sulfur containing fungicides and insecticides, sulfur being important nutritionally in some phases of the experiments. The soil was Blanton fine sand, level phase, from the Suwannee Valley Station, Live Oak, Florida. The batch used in 1954 had a pH value of 5.3, and the amount of available nutrients in pounds per acre were: CaO, 14; P_2O_5, 9; K_2O, 13; MgO, very low; and NO_3, very low. Galvanized tubs, 21½ inches in diameter at the top and 10¼ inches high, were used as containers. A small hole was put in the side at the bottom for drainage purposes. The tubs were coated inside with hot asphaltum and painted on the outside with aluminum paint. Each container held 130 pounds of soil. The treatments shown in Table 4 were replicated in three randomized blocks. The manner of application was indicated also in that table. Five Dixie Runner peanut plants were grown in each culture near the center of the tub. The peanuts were grown outside the greenhouse on a platform.

This test was an attempt to find out the value of an application of molybdenum, but turned out to be a practical demonstration of the im-

TABLE 4.—AVERAGE EFFECT OF FERTILIZER TREATMENT ON YIELD OF DIXIE RUNNER PEANUTS PER CONTAINER, NODULATION, COMPOSITION OF FOLIAGE ON OVEN-DRY AND SAND-FREE BASIS, AND PH OF SOIL AT END OF EXPERIMENT

Treatment[1]	Foliage Grams	Unshelled Mature Nuts Grams	Nodulation[3]	Soil pH at End[4]	Percentage Composition of Foliage[5]		
					N	S	Ca
1. C. except Ca and S	196	7.7	3.0	4.9	1.6	.07	1.07
2. C.	265	18.6	1.3	4.8	2.8	.18	1.24
3. C. except S	178	22.3	3.0	5.0	1.6	.06	1.46
4. C. except Mg	240	12.1	2.0	4.8	2.9	.19	1.18
5. C. plus Calcium carbonate[2]	186	119.3	1.0	5.6	2.8	.19	2.08
6. C. except Cu, Mn, Zn and B	260	12.0	1.7	4.8	2.9	.19	1.17
7. C. except Mo	257	11.7	2.0	4.9	2.1	.19	1.27
LSD 5%	30	16.2	1.3				
LSD 1%	43	22.7	1.8				

[1]Chemicals in all cases were reagent grade or best obtainable without repurification. C. is complete treatment and consisted of the following in pounds per acre (two million pounds soil): ammonium nitrate, 103; mono-calcium phosphate, 171; potassium chloride, 152; calcium sulfate, 600; magnesium acetate, 150; copper chloride, 10; zinc chloride, 10; manganese chloride, 10; boric acid, 2; and sodium molybdate, 0.4. This was equivalent to approximately 1200 pounds per acre of 3-8-8 fertilizer. The complete treatment without calcium sulfate eliminated essentially the calcium and sulfur in the fertilizer. Calcium lactate at 1056 pounds per acre was substituted for calcium sulfate where S was not in the fertilizer. All fertilizers were applied in the rooting area 3½ inches below the surface before seeding.

[2]The calcium carbonate at 600 pounds per acre was mixed in the top 3½ inches of soil before seeding.

[3]Estimates by three persons averaged. A rank of one was good, two was medium, and three was poor nodulation.

[4]The pH of soil before applying treatments was 5.3.

[5]Methods of chemical analysis published (23, 24).

[3]Courtesy Soil Testing Laboratory of the Soils Department, Florida Agricultural Experiment Station, Gainesville, Florida.

ortance of calcium in the fruiting zone. It is well known that soil olybdenum is more available under alkaline conditions. For that reason, o lime was applied to the soil, except in one case where 600 pounds of alcium carbonate per acre was mixed in the fruiting area. The fertilizer reatments were put in the rooting zone, and the complete treatment ontained enough calcium sulfate for good foliage color and growth. ither a molybdenum or a sulfur deficiency caused the foliage to be a ghter green or yellow in color. The yields of peanuts (Table 4) were xtremely small except where calcium carbonate was mixed in the fruiting rea, increasing the yield more than 600 percent. Calcium, sulfur, and pos- ible molybdenum increased nodulation. The pH of the soil originally as 5.3, and at the end of the test, in all cases except where calcium car- onate was applied, it was slightly lower. The carbonate slightly in- reased the pH value. Comments on the chemical composition of the oliage will be made in a later section.

More extensive experiments were conducted in the greenhouse in 955 (27, 28) using another batch of the same Blanton fine sand, level hase, from the Suwannee Valley Station. This soil had a pH of 5.3, and he readily available nutrients[4] in pounds per acre were as follows: CaO, 6; MgO, trace; P_2O_5, 18; K_2O, 22; and NO_3, very low. The boron[5] con- ent was 0.05 ppm.

Fifteen-gallon soft-glass carboys (15 inches inside diameter) were cut n half, and the neck portions used for containers. Operation of experi- nents with this type of container has been described (23, 24). Each con- ainer was filled with 60 pounds of air-dry soil. The top 2½ inches (ap- roximately) of soil was considered the fruiting zone and the lower por- ion the rooting zone. Treatments designated for the different zones were nixed in the soil of that zone. The two zones were separated by a layer f approximately 1½ inches of soil to which no treatment was added. The reatments, given in Table 5, were replicated four times in randomized locks. Four Early Runner peanut plants were grown near the center of ach culture. Soil samples were taken just before harvest. The manner f harvesting, curing, and grading of the peanuts has been published (23). The results are reported in Table 5 and 6.

Calcium in the fruiting zone increased the yield of peanuts almost 00 percent over the same calcium treatment in the root zone. The same mount of calcium added to both zones did not increase yields over those or fruiting-zone application only. Furthermore, without a calcium ap- lication in the fruiting zone, the grades of peanuts, as measured by shelling ercentage of good peanuts (Table 5), were poor. The pH value of the oil before the experiment was begun was 5.3. The treatments may have ffected the reaction of the soil during the growing season, but at the nd of the experiment, the pH value of the soil in the fruiting area in most ases had changed very little. The pH values of the soil in the rooting one at the end of the experiment in most cases were appreciably lower. The main exception was where sulfur was not applied. In that case, the H values of both the rooting and fruiting zone increased. The amount f calcium applied in these tests was not heavy. The results indicate that

[4]See footnote previous page.

[5]Courtesy of H. W. Winsor, Soils Department, Florida Agricultural Experiment Station, Gainesville, Florida.

TABLE 5.—AVERAGE EFFECT OF FERTILIZER TREATMENT ON YIELD OF PEANUTS PER CONTAINER, SHELLING PERCENTAGES, AND pH OF SOIL AT END OF EXPERIMENT

Treat. No.	Treatment[1] Root	Fruit	Tops Grams	Unshelled Mature Nuts, Grams	Shelling Percentages Based on Weight Unshelled Peanuts[2] Sound & Mature Nuts	Shrivels	Hollow Heart Defect	Dark Embryo	pH of soil at end of Experiment[3] Fruiting Zone	Rooting Zone
1	C	None	247	35.1	28.3	4.3	2.1	3.6	5.1	4.5
2	None	C	165	96.2	68.6	2.4	2.4	1.0	5.1	4.4
3	C	Ca, Mg, S, B	189	99.8	69.9	2.8	0.3	1.1	4.9	4.2
4	C	Ca	189	94.9	66.8	2.6	2.7	0.1	5.3	4.6
5	—K	Ca	85	20.1	79.5	1.4	0.0	0.0	5.4	4.9
6	—Ca	Ca	168	94.1	68.5	2.1	2.0	0.1	5.1	4.3
7	—Mg	Ca	155	90.7	70.8	1.0	1.4	0.0	5.2	4.6
8	—S	Ca	80	54.9	72.8	3.2	0.2	0.3	5.6	5.8
9	—Zn	Ca	201	89.6	69.5	2.8	2.1	0.7	5.3	4.5
10	—B	Ca	214	35.7	32.5	2.5	30.3	1.3	5.2	4.5
11	—Mo	Ca	147	95.3	71.0	2.9	0.8	0.2	5.3	4.5
LSD 5%			14.0	9.5	6.3	1.3	3.4	2.3		
LSD 1%			18.9	13.0	8.5	1.8	4.6	3.1		

[1]C indicates complete fertilizer and minus sign indicates element not applied in the fertilizer. Chemicals in all cases were reagent grade or best obtainable with repurification. The complete fertilizer consisted of the following in pounds per acre (two million pounds soil): Ca $(H_2PO_4)_2.H_2O$, 142; KCl, 127; Ca $SO_4.2H_2O$, 500; Mg $(C_2H_3O_2)_2.4H_2O$, 167; CO $(NH_2)_2$, 119; Cu $Cl_2.2H_2O$, 5; Zn Cl_2, 5; Mn $Cl_2.4H_2O$, 5; H_3BO_3, 1.7; and Na_2 $MoO_4.2H_2O$, 0.3. This is equivalent to approximately 1,000 pounds per acre of 5-8-8 fertilizer. The minus sulfur fertilizer was prepared by eliminating calcium sulfate from the complete treatment and substituting for it 880 pounds calcium lactate per acre. The minus calcium fertilizer was prepared by eliminating calcium sulfate from the complete treatment and substituting for magnesium, potassium and nitrogen sources the following rates in pounds per acre: Mg $SO_4.7H_2O$, 192; K2 SO_4, 148; and (NH_4) 2 SO_4, 262. Calcium lactate at 880 pounds per acre supplied calcium, only, to the fruiting zone. In the one case where calcium, magnesium, sulfur and boron were supplied to the fruiting zone, the already indicated rates of calcium sulfate, magnesium acetate and boric acid were applied. All treatments were applied before seeding.

[2]Sieves used in grading had oblong openings 15/64 inch by 3/4 inch.

[3]The pH values of the soil samples from the replicates were uniform, so the values were averaged. The pH of the soil before treatments were applied was 5.3.

TABLE 6.—AVERAGE EFFECT OF FERTILIZER TREATMENTS ON THE CHEMICAL COMPOSITION OF PEANUTS

Treat. No.	Treatment[1] Root	Fruit	Percentage Composition[2] Expressed on Sand-free, Oven-dry Basis: Sound and Mature Shelled Peanuts Oil	S	N	P	K	Ca	Mg	Foliage S	N	P	K	Ca	Mg	Na
1	C	None	53.1	.18	4.7	.24	.40	.019	.14	.20	3.0	.15	.59	.69	.31	.10
2	None	C	55.9	.20	4.5	.21	.32	.026	.12	.20	2.9	.16	.66	.81	.27	.09
3	C	Ca, Mg, S, B	55.8	.20	4.6	.21	.28	.024	.14	.21	3.1	.17	.49	.89	.34	.07
4	C	Ca	55.5	.17	4.5	.22	.31	.023	.14	.22	2.9	.18	.47	1.07	.28	.09
5	--K	Ca	54.2	.19	4.9	.28	.41	.026	.16	.23	3.2	.23	.09	1.14	.27	.06
6	—Ca	Ca	56.5	.16	4.5	.22	.32	.026	.13	.08	2.8	.14	.47	.86	.16	.12
7	—Mg	Ca	56.5	.16	4.6	.21	.36	.026	.13	.17	3.0	.16	.61	1.15	.07	.09
8	—S	Ca	53.4	.09	4.0	.30	.50	.024	.16	.10	1.8	.14	.82	1.76	.34	.12
9	—Zn	Ca	55.2	.17	4.5	.21	.30	.026	.12	.15	2.6	.15	.53	1.06	.22	.10
10	--B	Ca	54.6	.20	4.9	.30	.39	.034	.15	.14	3.1	.18	.55	.95	.26	.08
11	--Mo	Ca	56.2	.17	4.5	.23	.40	.027	.14	.14	2.6	.17	.71	1.06	.24	.11
LSD 5%			1.3	.02	.11	.02	.05	.004	.01	.05	.24	.03	.14	.15	.04	.03
LSD 1%			1.7	.03	.15	.03	.06	.005	.02	.07	.32	.04	.19	.20	.05	.04

[1]Treatment notes for Table 5 apply to this table.
[2]Methods of chemical analysis published (23, 24).

pH of the soil, per se, is not the important consideration, but that the lack of a moderate supply of calcium in the fruiting zone is critical.

The results of the boron phase of this experiment together with a supplemental test have been published (23). Boron added to the fertilizer greatly increased yields as well as prevented the development of a hollow-heart defect of the nuts. There was a varietal difference in response to boron—the Early Runner variety giving a larger increase in yield of nuts than the Dixie Runner. A mild case of this deficiency on another soil under field conditions near Branford, Florida, was corrected by an application of boron.

Since the gypsum at the early blooming stage and sulfur dustings are common practices, it is not surprising that sulfates in the fertilizer have had only a moderate effect on the yields of peanuts under field conditions. This phase of the greenhouse experiments was planned to determine whether sulfate could be important nutritionally when added to the soil under conditions where insects and diseases were controlled without using for that purpose sulfur or sulfur containing compounds. Foliage of peanuts with sulfate in the fertilizer was green color, but without it was a lighter green or yellow color. The color of the plants was similar to that commonly associated with nitrogen deficient plants. Sulfate in the fertilizer increased the yield (Table 5) of peanuts about 73 percent. Thus, it appears that sulfate in the fertilizer could be very important, but more probably an adequate amount would be supplied indirectly through other operations.

From time to time since 1944, molybdenum has been applied to peanuts both in field and greenhouse experiments. Probably the best illustration of its effect was the 1955 greenhouse experiment with Blanton fine sand, level phase. The peanuts without an application of molybdenum were a lighter green or yellow color similar to plants which have been regarded as sulfur or nitrogen deficient. Sodium molybdate at 0.3 pounds per acre caused the peanuts to be a dark green color and increased the foliage yield about 28 percent (Table 5). Nut yields were almost identical with or without the treatment.

While it is not a part of these greenhouse experiments, the molybdenum phase of a 1959 field experiment (29) can be appropriately discussed here. Dolomite limestone was applied uniformly to the plots while the border areas had none. The peanuts in the border areas were a lighter green or yellow color while the ones with an application of dolomite were a normal color. Sodium molybdate was sprayed on some of the affected plants, and they changed to a normal green color within two weeks after the application. This suggests that the lime carried molybdenum or that it increased the availability of the molybdenum in the soil. To summarize the effect of molybdenum, it has almost always caused the foliage to be a darker green and frequently has increased the size of the foliage, but to date, in our tests, it has never caused a statistically significant increase in the yield of nuts.

The potash study of the 1955 greenhouse experiment with Blanton fine sand, level phase, from the Suwannee Valley Station was striking. An application of potash to the soil increased the yield (Table 5) of peanuts almost 500 percent. Without potash the growth of the plants was stunted, many of the leaves were reddish or brown on the margins and some of the stems were almost dead before harvest time. However, the quality of the peanuts produced without an application of potash to the soil was excellent as judged by the shelling percentage of sound and mature nuts

Table 5). In fact, the best peanuts were produced without potash. Apparently, the potash level of the soil limited yield but did not affect the quality of the peanuts.

Without an application of magnesium, the foliage of the peanuts in these greenhouse experiments were somewhat smaller (Table 5), but otherwise there was little effect. Chemical evaluations related to the greenhouse experiments will be discussed in another section.

SUMMARY OF RESPONSES TO FERTILIZATION

The results of fertilization of peanuts may be summarized by saying that the response has been rather erratic. Increases in yield from an application of fertilizer have been obtained in some cases, especially applications of potash, but in other cases, even when the soil had not been fertilized in recent years, no response was obtained. One might get the idea that fertility is not important for peanuts. This, however, is a mistake. The chemical composition of the plants indicates that relatively large amounts of nutrients are obtained from the soil (33), and nutrient solution studies (3, 10, 15) clearly indicate that any nutrient deficiency will have a marked detrimental effect on the plant. Greenhouse studies on the comparative utilization of radioactive phosphorus during a 70-day period (22) by peanuts, corn and tobacco on different soil types showed that for corn and tobacco the percentage of phosphorus from the fertilizer decreased from the first to the last sampling while for peanuts it was the opposite. It is, therefore, apparent that plants behave differently towards fertilization. Because of the complex nature of the peanut, it may be that such factors as time and manner of fertilization application, speed of availability, residual effects, combination with organic matter, lime situation, nematode problems, and disease and insect control have confounded the response to fertilization. Without other complications, it is safe to say that fertile soils will produce more peanuts.

EFFECT OF TREATMENTS ON CHEMICAL COMPOSITION

Thus far, little has been said about the effect of treatments on the chemical composition of this plant. Killinger *et al.* (32) in field experiments compared the effect of 300 pounds per acre of 2-10-8 or 2-10-4 with no fertilizer on the composition of different parts of the plant of different ages. The treatments seemed to affect the composition but the effect appeared to vary with age. These authors emphasized the importance of sulfur dusting and indicated that it increased the oil content of the peanuts about two percent. According to them sulfur appeared to increase the phosphorus, potassium and magnesium content of most plant parts.

Nutrient solution studies (3) have shown that a deficiency of any one of the major elements will cause a decrease in percentage composition of that element in the vegetative parts of the plant.

The sound and mature Dixie Runner nuts (17) of the copper experiment were analyzed for oil and nitrogen and the copper treatment had no effect in that respect. This suggests that as long as there is enough copper to cause the peanut to mature and fully develop such nuts are normal with regard to nitrogen and oil content.

While a statistical evaluation of the chemical analysis (Table 4) made

on the plant material for the 1954 greenhouse experiment was not made the results suggest that sulfur or calcium in the treatment increased the percentage content of the respective element in the foliage. Sulfur or molybdenum in the treatment seemed to increase the percentage of nitrogen in the foliage.

In the 1955 greenhouse experiment (27, 28) with Blanton fine sand Ca, K, Mg, S, Zn, B, and Mo were varied individually in different parts of the experiment, the other necessary nutrients being applied at what was considered to be an optimum uniform level. About two weeks before harvest, the foliage of the various containers was sampled by taking three inch sections from the growing tips of the plants. These samples, as well as the sound and mature shelled peanuts, were chemically analyzed for minerals and oil. The methods utilized have been published (23, 24). It should be pointed out before discussing the chemical analysis that zinc in these experiments appeared to have no effect on the peanuts, that Mo and Mg only increased foliage growth, but that the other elements had an effect on both foliage and nut yields. The analysis of the foliar samples (Table 6) show that the phosphorus content of all foliage samples was relatively uniform probably because there was no variation in the phosphorus content of the fertilizer used. Soil treatments having a lower level of calcium, magnesium, potassium, or sulfur produced foliage with lower percentage levels of the respective elements. A sulfur or molybdenum deficiency decreased the percentage of nitrogen in the foliage. Sulfur deficiency, however, increased percentage values for potassium, calcium, or magnesium. There were other differences in the chemical composition of the foliage associated with treatments, but the relationships are not clear.

It is well known (33) that maturity of fruit affects the composition of the nuts. One is ordinarily interested in sound and mature shelled peanuts so that fraction was used for chemical evaluations (Table 6). Sulfur deficiency caused the greatest variation in oil content, reducing it from 55.1 to 53.4 percent. Sulfur deficiency also had the greatest effect on sulfur and nitrogen content, reducing them from 0.17 and 4.5 to 0.09 and 4.0 percentages respectively. The phosphorus content of the shelled peanuts was relatively constant, as would be expected because of uniform phosphorus fertilization. The calcium content was low and varied only slightly ranging from about 0.02 to 0.04 percent. The magnesium content also was relatively constant. A potassium deficiency resulted in a higher percentage composition of that element in the nuts. Other deficiencies such as sulfur and boron gave higher potassium percentages for the nuts. The explanation of these higher potassium percentages is not completely understood, but since potassium is a mobile element, the higher percentage for this element is probably related in part to the corresponding decrease in yields.

The effect of sulfur in increasing the oil content of peanuts as given above is consistent with the findings of Killinger *et al.* (32), but the effect of this element on the percentage composition of some of the other elements is not in complete agreement with the results of those authors. It should be remembered that the sulfur in the experiments of the writer (27, 28) was an attempt to find out the nutrient relationships and was put in the soil in the oxidized form. The sulfur level was altered by juggling chemicals. For example, where sulfur was applied as calcium sulfate, it can be omitted by applying an equivalent amount of calcium as calcium lactate. On the other hand, Killinger and his colleagues (32)

nducted sulfur dusting experiments, and it has already been pointed t that sulfur dust has an appreciable effect on soil acidity. Thus the sults from the two types of experiments should not necessarily agree.

The chemical results could be summarized by saying that variations fertilizer treatments have much more effect on the composition of the liage than on well-developed seed. A deficiency of any major element, hen the other necessary elements are available, markedly decreased the rcentage composition of the foliage with respect to the deficient element. nder the same conditions, treatments had some effect on the analysis of ie seed, especially the more mobile elements.

NEW TYPE OF FIELD EXPERIMENT IN 1959

Greenhouse and other controlled experiments show that peanuts re- ond to fertilization, and yet under field conditions, yields are generally w and the response is erratic. It was assumed that there must be some- ing wrong with the manner of conducting field tests. For that reason an tempt was made to include in an experiment all the things that might lp to increase yield and thus approach maximum production. A paper ving the results of this different approach to peanut production has been repared for publication (29) elsewhere. The soil was Arredondo loamy ne sand and had a pH value of 5.6. Lime or fertilizer had not been ap- lied in recent years, and peanuts had not been grown on this soil since bout 1945. A cover crop of rye was plowed completely under with 2300 ounds of dolomitic limestone one month before seeding. Twenty-five undred pounds per acre of 4-12-12 fertilizer (containing micro-nutrients) mpared to no fertilizer had been broadcast on the plots just previous to lowing under the rye. A level seed bed which did not disturb turned- nder organic matter was used. Two row spacings, 12 2/3 inches and 38 nches apart, were compared. Two varieties, Early Runner and Virginia unner Ga. 26, were grown. The peanuts were seeded in all cases in the ws six to eight inches apart. Other practices used were: six pounds per cre dinitro pre-emergence weed killer, 800 pounds per acre gypsum on ie foliage, dusting for insects and disease, irrigation when desirable, and o cultivation. There was only one-third stand in the plots of the Virginia unner Ga. 26 because through error poor seed were obtained. Even so, his peanut yielded an average of 3,806 pounds per acre of good quality eanuts with close row-spacing and fertilizer. The Early Runner variety n close row-spacing with fertilizer averaged 4,759 pounds per acre (one lot yielding 5,014 pounds) of good quality peanuts. The Commodity redit support value per acre for the 4,759 pounds yield was $472.41. lose spacing had more effect on yield than fertilization, but fertilizer as relatively more effective with closer spacing. Harvesting and all oper- tions were completely mechanized.

It is impossible to ascertain whether all practices utilized were bene- icial, but since large yields were obtained, it would seem that none were specially detrimental. The experiment clearly indicates that the yield of eanuts per acre can be greatly increased.

RESEARCH FOR THE FUTURE

Too often the same type of experiment that has been done before is epeated. New things should be tried. It is of little importance to demon- trate the value of lime, since moderate amounts on soils low in it have had

generally a marked beneficial effect on peanuts. A different type of lime experiment, designed to show new relationships, might be important. The same is true of conventional fertilizer tests. Even though relatively large amounts of minerals are removed from the soil by this plant, response of the peanut to fertilization have not been striking. Time and manner of fertilizer placement, absorbing system of the plant, accumulation of residual fertilizer in a form available to the peanut, or some other block has prevented responses to fertilization. Little progress along this line will be made until the blocks have been discovered. Nutrient solution studies have shown with certainty that peanuts will not grow in inert quartz with applications of distilled water. In variety tests and breeding experiments, the varieties are compared usually in wide rows. Recent as well as older evidence (29, 33) indicates that close row-spacing will give larger yields. Thus the plant breeder might not select the varieties best suited for close spacing. The use made of the peanut might be an important consideration. For example, curing would not be necessary if it were possible to ensile the green nuts and forage into a high protein feed for animals, or if it were desirable to extract the oil from the undried peanuts. When the nuts are to be used in such products as peanut butter, salted peanuts, or candy, they must be cured and be of high quality. It is desirable for all operations involved to be mechanized. Immediate combining after digging, followed by mechanical drying of nuts, might be of considerable importance in rainy periods when peanuts could be damaged by lying several days in the field. If immediate combining followed by mechanical drying were done and the peanuts were closely spaced, it would seem that bunch varieties would be better suited for that type of operation. Bunch varieties might utilize light and energy better under crowded conditions, and the upright nature of the growth would permit mowing and removal of a considerable amount of the foliage just before harvest. This combination could result in an increase in yield and facilitate harvesting. It is a well-known fact that growing peanuts continuously on the same soil is not a desirable practice, but one cannot get excited about comparing peanut rotations when the difference in the yield of rotations is likely to be no more than two or three hundred pounds per acre.

Yields during the last ten years in Florida have been relatively constant (13), averaging only 918 pounds per acre. The low productivity could be due to many individual factors or a combination of factors. Workers in Georgia (11) and Virginia (11) feel that southern blight and similar diseases are of importance, and it is possible that nematodes do more damage than is presently thought. Whatever the causes, the primary objective of experiments dealing with the production of peanuts is to find methods that will give larger yields of good quality peanuts and thus result in greater economic returns. Extensive use of labor is not profitable and mechanization is a necessity. We are living in a fast-moving age, and new approaches should be tried. One such approach (29) resulted in a yield of 4,759 pounds of good quality peanuts per acre. This suggests that research people can do something about production, if they will get out of the rut.

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Soybean Production In Western Florida[1]

R. L. SMITH[2]

Soybean production in Florida began in the late 1940's in Escambia County. The acceptance of the crop in Escambia County probably resulted from the good performance of soybeans when planted following potatoes in Baldwin County, Alabama. Acreage has increased rapidly and soybeans have replaced a great part of the corn acreage in Escambia County. The crop has also spread to adjoining counties so that west Florida now has a considerable acreage. Soybeans fit in very nicely with small grain and potatoes to make a double cropping system. The crop has a low labor requirement and a high investment in equipment, land, etc. However, the equipment can be used in producing small grain grown in rotation with it. With these combinations of crops, growers are not subjected to acreage controls or other restrictions. To date, the crop has not been affected by any serious disease or insect pest when grown continuously on the same soil.

Varieties: Tests to evaluate varieties for their performance in west Florida and breeding lines for their potential as new varieties were started in 1949 in cooperation with the U. S. D. A. and have continued to the present time. Varieties and breeding lines in uniform nursery trials of two maturity groups, each containing 12 entries, were grown in 1949. This work has been expanded over the years and at the present time uniform nursery trials are conducted for the three maturity groups designated VI, VII, and VIII. The three maturity groups contain varieties and breeding lines ranging from the earliest to the latest types adapted to Florida. Preliminary nurseries are grown each year for maturity groups VI and VII to aid in identifying the best breeding lines for testing in the more advanced test. A total of 36 varieties and breeding lines are evaluated each year in three replications of four row plots in the uniform nursery trials of maturity groups VI, VII and VIII. The preliminary nurseries usually contain 34 breeding lines and two check varieties each and are grown in four row plots replicated two times. Only entries that have been named and released are included in Table 1.

[1]Florida Agricultural Experiment Station Journal Series, No. 1044.
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TABLE 1.—COMPARABLE DATA FROM NAMED VARIETIES IN UNIFORM TEST GROUPS VI, VII AND VIII FROM 1949 TO 1958 YIELD IN BUSHELS PER ACRE

Group VI	1949-1958	1951-1958	1953-1958			
Ogden	36.5	35.4	36.6			
Lee		37.8	37.9			
Hood			32.8			
Group VII	**1949-1958**	**1949-1957**	**1949-1953**	**1952-1958**		
Jackson	38.8	37.0	38.3	38.6		
Roanoke		35.4	36.0			
Dortchsoy 31			38.8			
Lee				36.3		
Group VIII	**1949-1958**	**1949-1952**	**1950-1957**	**1951-1958**	**1954-1958**	**1956-1958**
J.E.W. 45	32.5	35.9	31.5	31.3	32.2	40.1
Acadian		29.8				
Majos			30.1			
Improved Pelican				26.0	26.8	34.6
Jackson					37.6	48.2
Yelnanda 53-116					32.0	40.2
Bienville						47.0

Along with the named varieties, a considerable number of lines, strains, etc. are being grown in trials each year. Entries not showing promise are replaced by promising lines from the preliminary tests. An average yield of 36.5 bushels was produced by Ogden over a period of 10 years. This variety is still being planted for early production. It yields well but will shatter if not harvested promptly. Over a comparable period of eight years (1951-1958), the average yield for Lee was three bushels more than Ogden. Lee matures about seven days later than Ogden, has excellent shatter-resistance and good quality seed. However, lodging will occur if the stand is too thick. Forty-five pounds of seed will produce a good stand as compared to 60 to 75 pounds of larger seeded varieties. Hood, a recent release, has not produced as well as Ogden and Lee except for the past two years. It matures five days earlier than Ogden.

In Uniform Test Group VII, Jackson and Lee are the only named varieties remaining. Roanoke and Dortchsoy 31, although making good yields, have other undesirable characteristics and have been dropped from the tests. They are no longer planted by farmers in the area. Yields of Jackson and Lee over a seven year period (1952-1958) are 38.6 and 36.3 bushels, respectively. Comparable yields for Jackson and Bienville show them to be superior to J. E. W. 45 and Yelnando 53-116. Other promising strains are being tested. Jackson No. 59, a new strain was included in the 1959 trials.

Dates of Planting: A date of planting experiment has been conducted with three to four varieties for a number of years. Planting dates began on April 15 and were spaced at semi-monthly intervals until August 1 of each year, giving a total of eight planting dates. Three replications of each variety were planted in randomized blocks at each date of planting. Fertilizer was applied at the rate of 600 pounds of 4-10-7 per acre 15 days after planting. At this time, the plants were approximately 2½ inches in height. Rate of seeding was based on 75 pounds of seed with a germination of 95%. A one rod section was harvested from the center row of each plot.

TABLE 2.—EFFECT OF DATE OF PLANTING ON YIELD OF SOYBEANS. YIELD IN BUSHELS PER ACRE

Date of Planting	Ogden	Lee	Hood	Roanoke	Jackson	Bienville
April 15	28	27	17	27	31	33
May 1	30	33	33	28	33	39
May 15	32	36	37	32	35	44
June 1	34	37	39	34	37	39
June 15	31	32	32	34	31	33
July 1	25	28	28	27	29	32
July 15	20	21	24	18	20	20
Aug. 1	16	14	14	12	14	12

All samples were threshed, cleaned, bagged and stored until they were air dried before weighing.

It was observed that the height of the beans at maturity was affected by the date of planting. This was especially true of the early maturing varieties such as Ogden, Lee and Hood. Maximum heights for all varieties were obtained with plantings on May 15, June 1 and June 15. Plantings prior to May 15 or after June 15 matured at a lower height. At the August 1 planting date, all varieties were approximately 12 inches in height at maturity. The yield was affected in the same manner with optimum yields being obtained between May 15 and June 15 (table 2). Generally speaking the yield would increase from 20 to 25 bushels for the April 15 planting to 40 to 45 bushels for the May 15-June 15 plantings. Thereafter, the yield declined sharply so that on the August 1 plantings, yields of only 10 to 15 bushels were produced.

No variation in quality of seed was observed except that in some seasons the quality from early plantings was damaged at maturity by excess rainfall.

The Rate of Seeding: The procedure was the same as in other tests. Rates of seeding, based on 95% germination, were 30, 45, 60, 75, 90, 105, 135, and 150 pounds per acre. Fertilizer was applied at the rate of 600 pounds of 4-10-7 per acre approximately 15 days after planting. The plots were harvested and threshed, and the seeds were cleaned, bagged and allowed to dry before weighing.

TABLE 3.—YIELDS OF SOYBEANS AS AFFECTED BY RATE OF SEEDING YIELD IN BUSHELS PER ACRE

Rate of Seed in Pounds	Ogden 1950-55	Lee 1954-57	Jackson 1954-57	Bienville 1957	Hood 1957
30	27	22	23	28	23
45	29	25	24	29	26
60	27	24	27	29	31
75	27	26	26	29	26
90	27	25	25	31	26
105	28	25	26	31	30
120	27	23	24	29	29
135	16	23	23	29	
150	22	25	25	29	

Variations in yields for rate of seeding are shown in Table 3 for 5 varieties of soybeans. There was on the average a consistently higher yield for 45 pounds of seed per acre than for the 30-pound rate. However, rates above 45 pounds per acre did not improve soybean yield. There were benefits of thicker stands other than yield that should possibly be considered in determining optimum rates of planting. When soil crusts formed, the presence of more seedlings with increasing rates of seeding, pushing against the crust permitted break-through and thicker stands. Thicker stands made weed control easier because of shading. On the other hand rates above 90 pounds per acre tended to lodge. When all factors are taken into consideration rates of 60 pounds per acre might be recommended.

Row Width: A row width experiment was conducted over a three year period with Ogden soybeans. Various rates of seed and fertilizer were included. Row widths were: 12, 18, 24, 30, 36 and 42 inches. Rates of seed and fertilizer were: (A) 600 pounds 4-10-7 and 60 pounds of seed per acre, (B) Fertilizer applied at the rate of 600 pounds of 4-10-7 per acre and seeding rates at a rate of 60 pounds per acre per row equivalent to the rate applied in rows 36 inches apart. (C) Fertilizer and seed applied at a rate per row to equal that applied at 600 pounds of fertilizer and 60 pounds of seed per acre respectively in 36 inch rows.

Yields for 42 inch row widths, as shown in Table 4, were appreciably lower for all rates of fertilizer and seed. Yields for all other row widths were approximately equal when 600 or more pounds of fertilizer and 60 or more pounds of seed were used. Where each row was fertilized and seeded at rates per row to equal 600 pounds of fertilizer and 60 pounds of seed on 36 inch rows, yields decreased from 31 to 24 bushels as row width increased from 12" to 36". However, the gain in yield for close rows was more than offset by cost of extra seed and fertilizer.

Fertilizer: A fertilizer ratio experiment was conducted from 1949 to 1957 inclusive on unlimed soils suitable for production of soybeans. Requirement for sites was: soybeans must not succeed a leguminous cover crop or potatoes. Fertilizer was applied by hand in furrow and lime was

TABLE 4.—EFFECT OF WIDTH OF ROW ON YIELD OF SOYBEANS 1951-1953

Row Width Inches	Yield in Bushels Per Acre A	B	C
12	29	25	31
18	27	26	28
24	27	26	26
30	26	24	25
36	27	25	24
42	24	23	23

A—Fertilizer applied at rate of 600 pounds per acre of 4-10-7 and the seeding rate was 60 pounds per acre.

B—Fertilizer applied at the rate of 600 pounds per acre of 4-10-7 and seeded at a rate per row to give 60 pounds per acre in rows 36 inches apart.

C—Fertilizer and seed applied at a rate per row to equal that applied at 600 pounds of fertilizer and 60 pounds of seed per acre respectively in 36 inch rows.

TABLE 5.—EFFECT OF VARIOUS FERTILIZER TREATMENTS ON YIELD OF SOYBEANS 1949-1957

Fertilizer Treatment 600 Pounds	Yield in Bushels Per Acre: 1 Ton Dolomitic Limestone	Yield in Bushels Per Acre: No Lime	Increases Due to Lime
0 -10-10	26.9	22.6	4.3
2½-10-10	28.2	24.7	3.5
5 -10-10	27.8	24.7	3.1
7½-10-10	28.6	25.2	3.4
5 -10-10	27.1	24.6	2.5
5 - 5-10	26.8	24.4	2.4
5 -10-10	27.8	24.7	3.1
5 -15-10	27.4	25.5	1.9
5 -20-10	27.9	25.6	2.3
5 -10- 0	27.1	23.6	3.5
5 -10- 5	27.6	24.3	3.3
5 -10-10	27.8	24.7	3.1
5 -10-15	28.5	24.3	4.2
5 -10-20	28.3	24.9	3.4

Seeding Rate 60 to 75 pounds per acre

broadcast by hand ahead of planting. Rod row sections were harvested from each of two center rows of each plot for yield. The following rates per acre of the three major plant food elements were used: Nitrogen—0, 15, 30 and 45 pounds; P_2O_5 and K_2O—0, 30, 60, 90 and 120 pounds. Three replications of each treatment were split, half receiving one ton of dolomitic limestone per acre and the other, no lime. Treatments and yield data are shown in Table 5. Yields are averages of a nine-year period.

The data in Table 5 show only a slight advantage for use of nitrogen, phosphorus and potash in production of soybeans under the conditions of these tests. Greater yield increases were obtained in the first few years of the experiment and this is probably due to increased use of fertilizer in the area. Only one distinct potash deficiency was observed in these tests and a favorable yield response was obtained for the use of potash. One ton of lime, as used in these tests, resulted in an average increase in yield of three bushels per acre.

TABLE 6.—THE EFFECT OF VARIOUS MINOR ELEMENTS ON YIELD OF SOYBEANS

Minor Element Treatment	Pounds Per Acre	Yield B/A
Esminel	60	21.0
Manganese Sulphate	25	21.3
Zinc Sulphate	25	21.1
Copper Sulphate	25	20.8
Magnesium Sulphate	60	21.6
Borax	15	20.4
Basic Slag	600	21.4
Check		21.4

Rate of Fertilizer: 600 pounds 4-10-7
Rate of Seed: 60-75 pounds per acre

A minor element experiment was conducted on the same location with the fertilizer ratio experiment. The following minor elements or mixtures were used: Esminel, manganese, zinc, copper, magnesium, boron and basic slag. These materials, at rates shown in Table 6 were applied in a mixture of 600 pounds of 4-10-7 (with sand filler).

No appreciable increases in yield were obtained for the use of minor elements and no recognizable deficiencies have been observed in the area. This is in agreement with results from other crops.

SUMMARY

These data indicate that Lee and Jackson varieties produce higher yields than Ogden and Dortchsoy 31 in west Florida. They have excellent shatter resistance and good seed quality. Consequently, they are being recommended for planting. Bienville, a variety more recently released, comparable to Jackson in yield and maturity, is tentatively recommended.

Maximum yields were obtained from Ogden, Lee, Hood, Jackson and Bienville varieties when planted from May 15 to June 15.

Seeding rates above 45 pounds per acre gave no appreciable increase in yield. However, where crusts had formed, better stands were obtained with higher rates of seeding. Thick stands facilitated weed control. On the other hand, lodging occured with rates of 90 pounds per acre or more.

Where recommended rate of fertilizer and seed were used, row width had very little effect on yield.

Application of nitrogen, phosphorus and potash resulted in small but significant yield increases. One ton of lime, as used in these tests, produced an average gain of three bushels.

No appreciable gain in yield was obtained from use of minor elements, and no recognizable deficiency symptoms were observed in the area.

Early Work With Field Crops In Northern and Western Florida

R. W. Lipscomb and R. W. Wallace[1]

Mobile Units of the North Florida Experiment Station were established by an act of the state legislature in 1941. The purpose of these units was to conduct cooperative experiments on general field crops with farmers in northern and western Florida. It was thought that a twofold objective could be realized by this type of research. First, it would demonstrate to the farmer on his own farm that improved methods of fertilization as well as increased rates of fertilizer would be economical. Second, results obtained from the experiments would serve as a guide to the general fertility level of the various soil types in north Florida. Such information would aid in future fertilizer recommendations for a specific crop.

Several problems were confronted in evaluating results from these experiments. Some of them were as follows: (1) information on the past history of the soil was not available; (2) soil samples were not taken from the experimental areas; (3) equipment and land preparation were not always adequate.

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The purpose of this paper is to summarize the data from fertilizer tests with corn, peanuts and cotton, obtained by the Mobile Units.

CORN

Corn occupies more acreage than any other crop in northwest Florida. There are some counties in which other crops such as tobacco, peanuts and watermelons bring in a larger cash return. Most of the corn is fed as grain to livestock on the farm where it is produced; the remainder is sold commercially.

Prior to the middle 1940's much of the corn was planted in wide rows and interplanted with peanuts, velvet beans, or cowpeas. Open pollinated, one eared varieties were planted. Little or no commercial fertilizer was applied.

According to the Florida State Marketing Bureau report, the average state corn yield has increased from 11.5 bushels per acre in 1940 to 26.0 bushels per acre in 1958. Most of the increase has occurred between 1948 and 1958. This is the result of the increased use of complete fertilizers at planting, higher rates of nitrogen sidedressing, planting hybrid seed and closer spacings.

CORN FERTILIZER EXPERIMENT

Fertilizer experiments were conducted on 23 farms in 1942, 1943, and 1944 to determine the effect of various fertilizer mixtures on the yield of corn. Treatments included variations from the standard 4-8-4, applied in the drill at the rate of 300 pounds per acre at planting. Other treatments were 250 pounds of dolomitic limestone and a minor element mixture containing copper, zinc, magnesium, and boron applied in the row. Results of these tests are presented in Table 1.

Corn receiving 300 pounds of 4-8-4 per acre averaged 8.1 bushels more than corn receiving no fertilizer. Applications of fertilizer in the row containing 6, 12 and 18 pounds per acre of nitrogen increased the yield of corn 2.3, 4.6 and 6.8 bushels per acre. This represented an increase of approximately 2 bushels of corn for each increment of 6 pounds of nitrogen. Thirty-six pounds of P_2O_5 or K_2O increased the yield approximately 3.5 bushels per acre. The addition of dolomitic limestone or minor elements to the fertilizer mixture gave a slight decrease in yield.

Corn is fertilized today with approximately 6 times the amount of N and K_2O and three times the amount of P_2O_5 used as a base in these earlier experiments.

RATES OF NITROGEN AS SIDEDRESSING FOR CORN

An experiment was started in 1946 and continued for six years on 27 farms to determine the most economical rate of nitrogen for corn production under northwest Florida conditions. A basic application of 600 pounds of 2-14-14 was applied when the corn was planted. Additional nitrogen was applied at the rates of 20, 40, 60, 80, 120, and 160 pounds per acre in one application approximately 40 days after planting. The rates of 80, 120, and 160 pounds were also applied in split applications. Average yields for the six-year period are presented in Table 2. The basic treatment

TABLE 1.—CORN FERTILIZER EXPERIMENT (1942-1944).

Fertilizer Treatment (300 lbs. per Acre)	Yield of Corn in Bushels per Acre: Unit No. 1 Avg. 14 Farms	Unit No. 2 Avg. 9 Farms	Average Both Units 23 Farms	Increase over No N	Increase over No P_2O_5	Increase over No K_2O	Increase over No 4-8-4
0-0-0	15.4	17.4	16.4				
0-8-4	18.5	21.6	19.9				
2-8-4	20.8	23.7	22.8	2.3			
4-8-4	23.7	25.3	24.5	4.6			
6-8-4	26.4	26.9	26.7	6.8			
4-0-4	21.9	24.5	23.2				
4-4-4	23.5	26.7	25.1		1.9		
4-8-4	24.1	27.3	25.7		2.6		
4-12-4	26.0	27.5	26.8		3.6		
4-8-0	21.3	26.1	23.7				
4-8-4	24.2	27.3	25.8			2.1	
4-8-8	25.6	28.1	26.9			3.2	
4-8-12	27.0	28.2	27.6			3.9	
4-8-4	24.0	25.1	24.6				
4-8-4 (a)	23.7	23.8	23.8				—0.8
4-8-4 (b)	23.2	23.6	23.4				—1.2

(a) Plus 250 pounds dolomitic limestone
(b) Plus minor element mixture
(1) Copper sulphate—10 lbs.
(2) Zinc sulphate—5 lbs.
(3) Magnesium sulphate—10 lbs.
(4) Manganese sulphate—10 lbs.
(5) Boron—5 lbs.

of 600 pounds of 2-14-14 without additional nitrogen as a sidedressing produced 35.2 bushels of corn per acre. The addition of 20, 40, 60, 80, 120, and 160 pounds of nitrogen increased the yield 6.3, 11.0, 13.5, 14.3, 15.1, and 16.0 bushels per acre, respectively. Although yield increases were obtained for all rates of nitrogen, the responses were narrower above 60 pounds of nitrogen per acre. Split applications of nitrogen were no better than single applications.

CORN VARIETY AND FERTILIZER EXPERIMENT

A combination variety and fertilizer experiment was conducted on a Ruston fine sandy loam soil in Jefferson County in 1946-1947. Dixie 18, Florida W-1, Florida W-2, Florida S-1, and a local, one eared, open-pollinated variety were compared. The experiment contained eight replications. Four replications of each variety received 600 pounds per acre of 4-10-7 fertilizer at planting and was sidedressed with 56 pounds of N and 18 pounds of K_2O, making a total of 80-60-60. The other four replications did not receive any fertilizer. Data for this experiment are presented in Table 3. The average yield of corn for the four hybrid varieties was 44.9 bushels per acre with fertilizer and 28.7 bushels without fertilizer. The local variety produced 33.4 bushels for the fertilized plots and 27.2 bushels

TABLE 2.—RATE OF NITROGEN AS SIDEDRESSING FOR CORN (1946-1951).

Additional N as Sidedressing in Pounds per Acre	Yield of Corn in Bushels per Acre			Increase over No Nitrogen
	Unit No. 1 22 Farms	Unit No. 3 5 Farms	Average 27 Farms	
0	30.7	39.7	35.2	
20	35.6	48.3	41.5	6.3
40	38.9	53.5	46.2	11.0
60	40.5	56.8	48.7	13.5
80	41.8	57.1	49.5	14.3
120	43.5	57.4	50.3	15.1
160	44.0	58.4	51.2	16.0
80*	41.0	56.9	48.9	13.7
120*	43.1	58.4	50.8	15.6
160*	43.5	58.0	50.8	15.6

*Half of nitrogen applied 40 days after planting and half two weeks later.
Variety: Dixie 18
Fertilizer: 600 pounds 2-14-14 per acre at planting.
Spacing: 42-inch rows, 18 inches in drill.

for the unfertilized plots. The average increase in yield for the four hybrids due to fertilizer was 16.2 bushels per acre, whereas the increase for the local variety was only 6.2 bushels. These data indicated that factors other than fertilizer limited the yields of the open pollinated varieties.

CORN SPACING AND FERTILIZER EXPERIMENT (1944-1946)

Experiments were started in 1944 and continued for three years on 19 farms to determine the proper spacing and economical rate of fertilization for corn. Corn was spaced 12, 18, 24, 30, 36 and 42 inches in 42-inch wide rows. It was fertilized at rates of 200, 400, and 600 pounds per acre of 4-10-7 at planting and sidedressed with 16 pounds of nitrogen. The results are presented in Table 4. At the lower two rates of fertilizer the thinner stands gave higher yields while at the highest rate stands made very little difference. Increasing the fertilizer from 200 to 400 pounds per acre in-

TABLE 3.—CORN VARIETY AND FERTILIZER EXPERIMENT (1946-1947).

Variety	Yield of Corn in Bushels per Acre		
	Fertilized	Not Fertilized	Increase over No Fertilizer
Dixie 18	45.6	31.4	14.2
Fla. W-2	48.1	28.6	19.5
Fla. S-1	43.1	28.8	14.3
Fla. W-1	42.6	26.0	16.6
Local*	33.4	27.2	6.2

*One-eared, open-pollinated variety.
Fertilizer: 600 pounds 4-10-7 at planting plus 56 pounds of N and 18 pounds of K_2O as sidedressing; total 80-60-60.
Soil Type: Ruston fine sandy loam.
Previous Crop: Corn and velvet beans unfertilized.

TABLE 4.—CORN SPACING AND RATE OF FERTLIZER (1944-1946).

Rate of Fertilizer in lbs. per Acre	Spacing in Drill in Inches	Yield of Corn in Bushels per Acre			
		Unit No. 1 Average 6 Farms	Unit No. 2 Average 7 Farms	Unit No. 3 Average 6 Farms	All Units Average 19 Farms
200	12	18.9	23.0	33.1	25.0
	18	21.3	26.8	35.2	27.8
	24	22.1	23.6	34.9	26.9
	30	23.7	23.0	32.3	26.3
	36	24.1	24.8	33.7	27.5
	42	23.6	23.0	31.7	26.1
Ave.					26.6
400	12	19.9	27.3	34.3	27.2
	18	22.4	28.6	35.6	28.9
	24	23.6	27.6	34.9	28.7
	30	26.1	29.6	33.8	29.8
	36	26.2	32.5	33.1	30.6
	42	26.2	33.8	31.5	30.5
Ave.					29.3
600	12	22.4	34.4	35.6	30.8
	18	24.1	36.4	37.5	32.7
	24	27.1	34.9	38.5	33.5
	30	28.5	32.7	37.4	32.9
	36	29.2	30.1	33.8	31.0
	42	28.7	30.0	34.4	31.0
Ave.					32.0

Fertilized at planting with 4-10-7 at the above indicated rates and sidedressed with 16 pounds of N.

creased the yield 2.7 bushels and from 400 to 600 pounds per acre gave an additional 2.7 bushels. The small increases were probably due to factors other than fertilizer limiting yields.

PEANUTS

Peanuts are well adapted to the climate and soils of northwest Florida and large acreages are planted. At first most of the peanuts were hogged off but the increased demand for peanuts and the high price paid for the crop during the war caused a considerable increase in acreage harvested for nuts. When harvested by hogging-off, peanuts have very little effect on the fertility level of the soil. When peanuts are harvested by the stack-pole method, both the peanuts and hay are removed from the soil. This method depletes the soil of all the major plant nutrients and peanut yields decline, especially when continuous cropping to peanuts is practiced. Experiments were initiated to determine if the soil fertility and yield of peanuts could be improved by fertilization and crop rotation.

Peanut Fertilizer Experiment. Comparisons of fertilizer mixtures containing variations from a basic 2-10-4 mixture were made for three years. Other treatments were: application of potassium in the planting mixture

and at emergence; application of gypsum, dolomitic limestone, minor elements and sulfur as a dust for the control of leaf spot. Average yields for the various treatments are presented in Table 5. None of the variations produced higher yields than 300 pounds per acre of 2-10-4 fertilizer plus copper sulfur. There was no difference in yield when the potassium was applied either at emergence or when it was increased from 4 to 8 percent in the mixture. Increasing the superphosphate from 10 to 16 percent did not affect the yields. Basic slag was comparable to superphosphate in the production of peanuts. There was little difference in yields from various amounts of nitrogen. When gypsum was applied at the rate of 200 pounds per acre, there was an increase of 67 pounds peanuts. Neither dolomitic limestone nor minor elements showed a consistent increase in yield over 2-10-4 fertilizer. When peanuts were dusted with three applications of sulfur (20 pounds per acre) and copper-sulfur (20 pounds per acre) the average yield was increased by 116 and 144 pounds respectively. The sulfur dust treatment was most consistent of any in increasing the yield of peanuts.

TABLE 5.—YIELD RESPONSE OF PEANUTS TO FERTILIZER TREATMENT. 1942-1944

Fertilizer Treatment 300 pounds per acre	Average yield 16 Farms	Increase over No Fertilizer
0-0-0	759	
0-10-4	926	167
2-10-4	918	159
4-10-4	879	120
0-10-0 Superphosphate	858	99
0-10-0 Basic slag	836	77
2-10-4 Basic slag	910	151
2-10-8	919	160
2-10-0 (8% K_2O sidedressing)	926	167
2-16-4	941	182
2-10-4 plus 200 lbs. gypsum	1003	244
2-10-4 plus 500 lbs. Dolomite	945	186
2-10-4 plus minor elements*	917	158
2-10-4 plus copper sulfur	1020	261

*10 pounds copper sulphate; 10 pounds magnesium sulphate; 5 pounds zinc sulphate; 5 pounds boron.

A COMPARISON OF DIXIE AND FLORIDA RUNNER VARIETIES

A yield comparison of Dixie and Florida Runner peanuts was made on 24 farms during 1945 and 1946. One-acre blocks of each variety were planted at each location and one-half of each variety was dusted with three applications of sulfur. The data are presented in Table 6. Dixie Runner produced 100 pounds per acre more peanuts than Florida Runner. Dusting with sulfur increased the yields of Dixie Runner and Florida Runner 96 and 121 pounds per acre, respectively. More peanuts of the Dixie Runner were left in the soil at harvest. This is probably due to the fact that Dixie Runner is 10 days earlier than Florida Runner and both varieties were harvested at the same time. A total yield, including peanuts left in the soil, showed that Dixie Runner yielded 200 pounds per acre more than Florida Runners.

Concealed Damage.—A condition known as concealed or hidden damage has been of much concern and interest in recent years. The damage is confined to runner types of peanuts and is rarely found in Spanish types. The damage cannot be detected until the peanuts are split into halves, therefore the name "concealed" damage. The damage is characterized by a dark interior color accompanied by a bitter taste. There are many theories concerning the cause of this damage. During the 1945 season, a study was made to determine the relationship between methods of stacking and concealed damage. Variations in the farmers style of stacks and time interval from digging to stacking were made with both Florida Runner and Dixie Runner varieties. Samples from these different methods of curing were collected and taken to a commercial buyer for grading. Data in Table 7 indicated no relationship between methods of stacking and curing, and the occurrence of concealed damage. However, an average of all methods of curing showed less concealed damage in the Dixie Runner than in Florida Runner. It was concluded that concealed damage was a varietal characteristic and not related to method of stacking or curing.

COTTON

The production of cotton in Florida declined rapidly during World War II. The acreage in 1940 was 65,000 acres and in 1946 was 22,000 acres. This rapid decline was due to a shortage of labor and higher cash returns from peanuts, other cash crops, and livestock. Climatic conditions in North Florida do not appear to be favorable to the commercial production of high grade cotton.

Cotton Fertilizer.—A cotton fertilizer analysis experiment was conducted on 22 farms during 1942, 1943, and 1944. Variations in N, P_2O_5 and K_2O from the standard 4-8-4 were applied at the rate of 300 pounds per acre. Other treatments involved split applications of nitrogen, extra nitrogen as sidedressing, dolomitic limestone, and minor elements. Yield data are presented in Table 8. Applications of 6, 12, and 18 pounds per acre of N increased the yield of seed cotton 65, 156, and 198 pounds above the check. Applications of 12, 24, and 36 pounds per acre of P_2O_5 increased the yield of seed cotton 102, 168 and 175 pounds respectively. Likewise, applications of 12, 24, and 36 pounds per acre of K_2O increased the yield of seed cotton 120, 172 and 230 pounds per acre. Withholding one-half the nitrogen at planting and applying as sidedressing increased the yield 157 pounds of seed cotton per acre over plots that received like amounts of nitrogen at planting. Twenty-four pounds of additional nitrogen applied as a sidedressing increased the yield 385 pounds per acre over no sidedressing.

Dolomitic limestone at the rate of 250 pounds per acre applied in the drill at planting had no effect on the yield of cotton.

Minor elements mixed with the fertilizer and applied at planting did not increase the yield.

CONCLUSION

Experimental work demonstrated the possibility of increasing corn yields by the use of larger amounts of complete fertilizer and nitrogen sidedressing, closer spacing, and hybrid varieties. These practices are now in general use by farmers in northwest Florida.

TABLE 6.—COMPARATIVE YIELDS OF DIXIE AND FLORIDA RUNNER PEANUTS WITH AND WITHOUT SULPHUR DUST. 1945-1946.

Variety	Treatment	Yield — Pounds of Peanuts Per Acre: Mobile Unit No. 2 Milton Area Average 8 Farms	Mobile Unit No. 3 Marianna Area Average 16 Farms	Average 2 Units 24 Farms	Increase from Sulphur	Peanuts Left in Soil
Dixie Runner	No Sulphur	1216	996	1106		305
Dixie Runner	Sulphur	1356	1048	1202	96	273
Florida Runner	No Sulphur	1072	919	996		197
Florida Runner	Sulphur	1209	1025	1117	121	156

Fertilizer—300 pounds 2-10-4 per acre.

TABLE 7.—COMPARATIVE GRADES OF DIXIE AND FLORIDA RUNNER PEANUTS.

Location	DIXIE RUNNER: Percent Shriveled Seed	Percent Visible Damage	Percent Concealed Damage	Percent Sound Mature Seed	Percent Total Meats	FLORIDA RUNNER: Percent Shriveled Seed	Percent Visible Damage	Percent Concealed Damage	Percent Sound Mature Seed	Percent Total Meats
Mobile Unit 1 (2 Farms) Monticello Area	1.90	0.50	1.30	69.2	72.9	1.00	6.40	8.90	61.5	77.8
Mobile Unit 2 (3 Farms) Milton Area	1.48	2.56	1.50	68.5	73.5	1.50	3.50	10.10	57.5	72.6
Mobile Unit 3 (6 Farms) Marianna Area	1.36	3.48	2.40	67.5	74.7	1.08	4.25	7.50	61.2	74.1
Average	1.58	2.18	1.73	68.4	73.7	1.43	4.72	8.83	60.1	74.8

Samples Graded—
Monticello Area—10 of each Variety
Milton Area—15 of each Variety
Marianna Area—30 of each Variety

TABLE 8.—COTTON FERTILIZER EXPERIMENT (1942-1944).

Average Yield for Three Years on 22 Farms

Fertilizer Treatment	Pounds of Seed Cotton per Acre			
	Unit No. 1 Average 11 Farms	Unit No. 2 Average 11 Farms	Average 22 Farms	Increase over
				No N
0-8-4	637	721	679	----
2-8-4	690	802	746	67
4-8-4	774	895	835	156
6-8-4	846	908	877	198
				No P_2O_5
4-0-4	646	689	668	----
4-4-4	712	828	770	102
4-8-4	758	914	836	168
4-12-4	786	898	842	174
				No K_2O
4-8-0	574	734	654	----
4-8-4	725	822	774	120
4-8-8	801	850	826	172
4-8-12	891	877	884	230
				4-8-4
4-8-4	795	899	848	----
4-8-4 (a)	966	1044	1005	157
4-8-4 (b)	1153	1312	1233	385
4-8-4 (c)	821	878	850	2
4-8-4 (d)	830	875	853	5

(a) Half of nitrogen applied as sidedressing.
(b) Received 24 pounds of N as sidedressing.
(c) 250 pounds of dolomitic limestone applied.
(d) Minor elements added as in Table 1.

Even though there was no consistent response to the individual fertilizer elements used on peanuts, there was an overall increase in yield for a complete fertilizer.

Sulfur dust treatment for the control of leaf spot increased the yield of peanuts.

Concealed damage in runner peanuts was found to be a varietal characteristic and was not related to the method of curing the crop after harvest.

Fertilizer experiments showed the need for larger amounts of nitrogen, phosphorus and potassium than is in 300 pounds of 4-8-4 to increase yields of cotton. It is important that part of the nitrogen be used as sidedressing when the cotton is five weeks old.

Twelve Years' Progress On General Field Crops In Northern Florida[1]

L. G. THOMPSON, JR., R. W. LIPSCOMB AND W. K. ROBERTSON[2]

Corn, peanuts and soybeans occupy a large percentage of the cultivated land in northern Florida. The acute shortage of edible oil during and in the reconversion period following World War II resulted in high prices for peanuts and, consequently, a substantial increase in acreage for harvest. To obtain this increase in acreage, many farmers planted peanuts on the same land year after year. This practice seriously depleted organic matter and lowered soil fertility. On such soils both peanut and corn yields showed a progressive decline.

The investigation reported herein was conducted to determine the effect of rotational cropping, fertilizer, and lime on the yield of corn, peanuts, soybeans, and oats, grown on Norfolk loamy fine sand and Ruston fine sandy loam, two of the important soil types used for general farm crops in north Florida. Data obtained on them are applicable in general to several closely related soils such as Red Bay fine sandy loam, which with Ruston fine sandy loam and Norfolk loamy fine sand constitute approximately 50% of the cropland in north Florida.

This paper contains corn, peanuts, soybeans, and oat yields. Much of the cover crop data and soils analyses data have been reported for Ruston fine sandy loam and Norfolk loamy fine sand in individual publications (1, 2, 3). This is an attempt to combine the data.

EXPERIMENTAL PROCEDURE

A 40-acre field of virgin Norfolk loamy fine sand near Quincy, Florida, was surveyed into field blocks and plots during the winter of 1946-1947. Rotation and fertilizer experiments in randomized block design replicated four times were initiated in the spring of 1947. In 1949 rotation and fertilizer experiments were initiated on Ruston fine sandy loam at Mobile Unit No. 3 near Marianna, Florida. A soil sample was taken from each individual plot before any fertilizer or lime was applied. As the experiment progressed, soil samples were taken from time to time to study the changes brought about in the soil.

Red Rustproof No. 14 oats were planted the first three years, Southland oats the next five years, Seminole oats the next year, and Floriland oats the last year. As winter and summer cover crops, respectively, bitter blue lupine and Crotalaria spectabilis were planted the first five years, Alta blue lupine and Clemson Non-shatter soybeans the next four years, and Alta blue lupine and Lee soybeans the last two years. Florida W-1 hybrid corn was planted the first two years and Dixie 18 hybrid corn the last nine years of the experiment. Dixie runner peanuts were used throughout the experiments.

The lupines, soybeans and, in some of the cropping systems, oats were

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turned under for green manure. Corn was harvested and yields were reported as bushels per acre on 17% moisture basis. The corn stalks and native cover that grew in the corn were turned under. Both peanuts and vines were removed from the land. Peanut yields were reported as pounds per acre of unshelled nuts.

The fertilizer used in all experiments was made from Uramon (42 percent N), superphosphate (18 percent P_2O_5), and muriate of potash (60 percent K_2O), except for the last six years when ammonium nitrate (33.5 percent N) replaced Uramon. Corn received 10 pounds of zinc sulfate per acre annually, except for the last three years. Peanuts in all experiments were dusted three or four times each season with 20 pounds (per acre) of elemental sulfur-DDT mixture.

Each experiment was plowed by blocks. The direction of plowing was reversed every other time to minimize border effect.

Continuous crop and rotation experiments:

The continuous[3] crop and rotation experiment consisted of six continuous crop treatments, three two-year rotations, and two three-year rotations. A list of treatments appear with the yield data in Tables 1 and 2. Each crop in the two and three-year rotations was grown every year. This was accomplished by alternating the two-year rotations between two series of plots and the three-year rotations among three series of plots.

Each year corn and oats for grain were fertilized with 500 pounds per acre of 2-10-8 fertilizer at planting time on Norfolk loamy fine sand. On Ruston fine sandy loam corn was fertilized annually with 500 pounds of 4-10-7 fertilizer. For the first five years corn was top-dressed with 32 pounds per acre of nitrogen from Uramon and oats with 32 pounds from nitrate of soda. Corn for the last six years and oats for the last five years were top-dressed with 32 pounds per acre of nitrogen from ammonium nitrate. Oats turned under received annual applications of 500 pounds per acre of 2-10-8 fertilizer the first three years and no fertilizer the last seven years. On Norfolk loamy fine sand, peanuts were fertilized with 400 pounds of 2-10-4 fertilizer per acre the first three years and 500 pounds per acre of 2-10-8 fertilizer the last eight years of the test. On Ruston fine sandy loam, peanuts were fertilized with 350 pounds of 2-10-4 the first four years and 350 pounds of 0-14-14 the last six years. Blue lupine and crotalaria received 300 pounds per acre of 0-14-10 fertilizer the first three years and no fertilizer during the last seven years. Soybeans were not fertilized.

Fertility experiments:

The treatments for the fertilizer experiment on Norfolk loamy fine sand consisted of three general levels of fertility and three levels each of nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O) arranged in a randomized block design with four replications. Treatments were made to all crops in a three-year rotation consisting of peanuts, lupine under the first year, corn, oats for grain the second year, and crotalaria under, oats under the third year. This was done by having three sets of plots for each treatment and rotating the crops among them. Since a different crop was planted on each set of plots the first year, all crops received all treatments every year. The rates of fertilizer applied to each crop are shown with the yield data in Tables 6 to 11. The peanut plots received one ton of calcic lime in

[3]In this paper the term continuous crop refers to a crop planted on the same area in successive years.

TABLE 1.—EFFECT OF ROTATIONS ON CORN GROWN ON NORFOLK LOAMY FINE SAND.

Rotation	Year												Ave.
	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	
	bus/acre												
Continuous Corn:													
Corn only	42	36	58	58	49	29	42	33	48	48	61	44	46
Corn with crotalaria,* oats*	48	42	74	79	64	34	47	36	49	50	58	43	52
Corn with crotalaria*	48	39	70	82	62	35	50	38	51	55	67	44	53
Corn, lupine*	42	41	67	75	57	37	49	39	52	63	62	42	52
Average	45	39	67	74	58	34	47	36	50	54	62	43	51
Two-Year:													
Peanuts, lupine,* corn	43	49	72	84	62	42	49	41	52	58	58	45	54
Peanuts, lupine,* corn with velvet beans	38	45	69	75	59	36	50	40	51	57	58	44	52
Peanuts, lupine,* corn with crotalaria*	45	50	74	83	64	40	54	41	51	54	58	44	55
Average	42	48	72	81	62	39	51	41	51	56	58	44	54
Three-Year													
Peanuts, lupine,* corn, lupine*	42	48	71	87	63	41	53	40	53	64	57	42	56
Corn, oats*	43	44	69	82	69	36	50	42	53	58	68	32	54
Peanuts, lupine,* corn, oats for grain, crotalaria,* oats*	45	41	80	93	64	39	59	40	55	63	59	51	58
Average	43	45	74	87	65	39	54	41	54	62	61	43	56
L. S. D. (.05)	5	6	5	8	6	4	N.S.**	4	N.S.	3	N.S.	9	
L. S. D. (.01)	7	8	7	11	8	6		6		4			

*Crops plowed under as green manure.
Beginning in 1952, crotalaria was replaced by soybeans.
**N. S. signifies not significant.

TABLE 2.—EFFECT OF ROTATIONS ON CORN GROWN ON NORFOLK LOAMY FINE SAND

Rotation	Year 1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Average Last 7 Years
Continuous Peanuts:						bus/acre							
Peanuts only	1,900	1,470	820	1,360	2,010	790	740	490	780	580	650	530	650
Peanuts, lupine*	1,940	1,360	900	1,360	1,890	740	540	410	820	640	460	560	590
Average	1,920	1,420	860	1,360	1,950	760	600	450	800	610	560	540	620
Two-Year:													
Peanuts, lupine* Corn	1,740	1,660	1,080	1,390	2,220	1,310	1,220	900	1,270	920	1,060	1,380	1,150
Peanuts, lupine* Corn with velvet beans	1,890	1,670	990	1,360	2,410	1,330	1,120	940	1,380	1,110	890	1,380	1,190
Peanuts, lupine* Corn with Crotalaria	1,810	1,700	1,060	1,690	2,340	1,460	1,080	1,010	1,350	1,040	1,060	1,400	1,200
Average	1,810	1,680	1,040	1,480	2,320	1,370	1,140	950	1,330	1,020	1,010	1,390	1,180
Three-Year:													
Peanuts, lupine* Corn, lupine* Corn, oats*	1,960	1,800	1,050	1,440	2,200	1,520	1,530	1,220	1,620	1,080	1,000	1,340	1,330
Peanuts, lupine* Corn, oats for grain Crotalaria*, oats*	1,920	1,730	1,020	1,540	2,310	1,590	1,560	1,300	1,880	1,190	930	1,300	1,390
Average	1,940	1,760	1,035	1,490	2,260	1,560	1,545	1,260	1,750	1,130	970	1,320	1,360
L. S. D. (.05)	N.S.	230	180	280	220	250	130	172	250	130	190	180	
L. S. D. (.01)		320	250	N.S.	310	340	170	240	340	180	270	250	

*Crops plowed under as green manure.
Beginning in 1952 crotalaria was replaced by soybeans.

1956 and a second ton in 1957. All the other plots received two tons in 1957, making a total of two tons for all plots.

The treatments for the fertilizer experiment on Ruston fine sandy loam consisted of four levels each of nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O) arranged in a randomized block design with four replications. Treatments were made to all crops in a three-year rotation consisting of peanuts, lupine under, corn, oats for grain, soybeans, oats under. Oats were interplanted in vetch which replaced lupine in 1956 and 1957. This was done by using three sets of plots for each treatment and rotating the crops among them. A different crop was planted on each set of plots the first year. The rates of fertilizer applied to each crop are shown with the yield data in Tables 11 to 14.

RESULTS AND DISCUSSION

Norfolk Loamy Fine Sand:

Rotation Experiment. Yields of corn are shown in Table 1. Compared with the average of all continuous corn treatments, two-year rotations averaged three bushels higher and three-year rotations five bushels higher for the 12 years. However, the continuous corn interplanted with crotalaria or following lupine yielded only slightly less than two-year rotations and six to seven bushels more than continuous corn with no cover crop. The two-year rotations averaged eight bushels more and the three-year rotations 10 bushels more than continuous corn with no cover crop. In 1950, after the largest lupine crop of the 10 years reported, rotation corn yielded 23 to 35 bushels more than continuous corn with no cover crop.

The results show a close relationship between the total rainfall for May, June, and July and the corn yield from the three-year rotation of peanuts, lupine, corn, oats for grain, crotalaria, oats for 1949 through 1957. The correlation coefficient was 0.762, which was significant at the 5 percent level. These results indicate that rainfall is a very important factor in growing corn in north Florida.

Yields of peanuts are given in Table 2. For the first five years, the average yield of peanuts was about 200 pounds higher on the rotation than on the continuous peanut plots; yields were about the same in the two—and three-year rotations. For the last seven years the average yield of peanuts was 560 pounds higher on the two-year rotations and 740 pounds higher on the three-year rotations than on the continuous plots. These results show that for highest yields, peanuts should be grown only once in a three-year rotation.

For the last seven years the average yield of peanuts was 60 pounds higher for the three-year rotation of peanuts, lupine, corn, oats for grain, soybeans, oats than for the three-year rotation of peanuts, lupine, corn,—lupine, corn, oats. However, it may not be the best rotation, because there is only one instead of two corn crops for the three years. The soybeans might compensate for the corn crop if they were used for seed instead of green manure.

During the last seven years, there was more disease in the continuous peanuts than in the peanuts grown in the two-year rotation, and no disease was observed in the peanuts grown in the three-year rotation. Because of disease common to peanuts and lupine, the average yield of peanuts for the last seven years was 60 pounds lower following cover crops of lupine than following no cover crop.

TABLE 3.—EFFECT OF FERTILIZER ON CORN GROWN ON NORFOLK LOAMY FINE SAND.

Fertilizer			Year												Average
N	P_2O_5	K_2O	1947	1948	1949	1950	1951	1952	1952	1954	1955	1956	1957	1958	
	lbs/acre														
								bus/acre							
21	25	20	29	38	60	80	64	32	61	34	52	60	68	60	54
42	50	40	42	48	75	97	67	33	76	45	57	69	76	68	62
63	75	60	50	50	84	100	68	36	86	44	62	74	82	65	67
21	75	60	41	44	78	96	71	38	81	44	60	72	74	64	64
42	75	60	47	50	82	102	68	34	83	44	61	77	79	60	66
63	75	60	50	50	84	100	68	36	86	44	62	74	82	65	67
63	25	60	33	41	73	88	66	32	74	38	54	66	69	67	59
63	50	60	43	47	82	95	69	33	78	43	60	69	80	56	63
63	75	60	50	50	84	100	68	36	86	44	62	74	82	65	67
63	75	20	47	47	79	90	69	29	74	42	60	70	82	63	62
63	75	40	47	48	84	98	70	34	87	45	59	76	80	62	66
63	75	60	50	50	84	100	68	36	86	44	62	74	82	65	67
L. S. D. (.05)			5	6	5	8	6	4	7	4	4	4	6	N.S.	
L. S. D. (.01)			7	8	7	11	N.S.	N.S.	10	6	5	5	8		

TABLE 4.—EFFECT OF FERTILIZER ON PEANUTS GROWN ON NORFOLK LOAMY FINE SAND.

Fertilizer			Year												
N	P_2O_5 Lbs./acre	K_2O	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Ave.
								lbs/acre							
4	20	8	1,660	1,920	1,420	1,670	2,620	1,740	1,560	1,750	2,100	1,570	1,090	1,200	1,720
8	40	16	2,140	2,240	1,210	1,240	2,370	1,560	1,430	1,720	1,810	1,420	980	950	1,620
12	60	24	2,250	2,100	1,150	1,520	2,340	1,530	1,220	1,570	1,640	1,320	900	910	1,450
4	60	24	2,440	1,990	1,280	1,530	2,350	1,670	1,320	1,620	1,810	1,350	940	960	1,600
8	60	24	2,450	2,000	1,190	1,530	2,300	1,470	1,300	1,560	1,800	1,320	940	920	1,560
12	60	24	2,250	2,100	1,150	1,520	2,340	1,530	1,220	1,570	1,640	1,320	900	910	1,450
12	20	24	1,740	2,030	1,290	1,490	2,110	1,450	1,240	1,350	1,880	1,330	1,000	1,050	1,500
12	40	24	2,160	2,030	1,270	1,540	2,260	1,460	1,280	1,460	1,800	1,400	860	960	1,540
12	60	24	2,250	2,100	1,150	1,520	2,340	1,530	1,220	1,570	1,640	1,320	900	910	1,450
12	60	8	2,300	2,130	1,260	1,680	2,250	1,440	1,420	1,540	1,850	1,350	1,050	990	1,600
12	60	16	2,404	2,060	1,190	1,700	2,390	1,500	1,360	1,620	1,840	1,320	950	980	1,610
12	60	24	2,250	2,100	1,150	1,520	2,340	1,530	1,220	1,570	1,640	1,320	900	910	1,450
L. S. D. (.05)			170	250	N.S.	N.S.	N.S.	N.S.	150	170	190	N.S.	60	N.S.	
L. S. D. (.01)			230	N.S.					200	230	260		N.S.		

Fertility experiment. Table 3 shows the yields of corn with various rates of fertilizer. Increasing nitrogen, phosphate, and potash from the low to the medium rate increased the yield of corn eight bushels per acre for a 12-year average. A further increase of these three fertilizers to the high rate gave an additional increase in the yield of corn of five bushels per acre. Where phosphate and potash were high, increasing nitrogen from the low to medium rate increased the yield of corn only two bushels per acre; and a further increase of nitrogen to the high rate increased the yield of corn only one bushel per acre for a 12-year average. Since all the green manure crops in this rotation were well fertilized, they produced a good growth and added considerable nitrogen to the soil. As a result, only a small amount of extra nitrogen was needed to produce a high yield of corn. With nitrogen and potash at the high rate, increasing phosphate from the low to the medium rate increased the yield of corn four bushels per acre; and a further increase to the high rate increased the yield of corn four bushels per acre for an average of 12 years. With nitrogen and phosphate at the high rate, increasing potash from the low to the medium rate increased the yield of corn four bushels per acre, and a further increase to the high rate increased the yield of corn only one bushel per acre for a 12-year average. Since the lupine which was plowed under for corn was well fertilized and returned to the soil considerable phosphate and potash, there was not a large response to phosphate and potash above the medium rate. When corn was grown in a three-year rotation with all the crops well fertilized, the medium rate of nitrogen and the highest rate of phosphate and potash gave a 12-year average yield of 66 bushels of corn per acre. These results also show a correlation between the yield of corn and the total rainfall for May, June, and July. They also indicate that rainfall is a very important factor in corn production in north Florida.

Peanut yields from the fertilizer experiment are given in Table 4. When peanuts were grown in a three-year rotation with all the crops well fertilized, they did not respond to fertilizer. These results indicate that 200 pounds per acre of 2-10-4 fertilizer was the best rate to use in this experiment.

Oat yields with various rates of fertilizer are given in Table 5. Complete fertilizer gave a significant increase in the yield of oats for grain for eight years out of ten. Phosphate gave a significant increase in the yield of oats for eight years, potash for the last seven years, and nitrogen for two years.

Ruston Fine Sandy Loam:

Rotation Experiment. Yields of corn from the continuous crop and rotation experiment on Ruston fine sandy loam are shown in Table 6. The average yield of corn for the 11 year period was the same for the continuous corn as for the two-year rotations and only one bushel more for the three year rotations. Growing a green manure crop such as crotalaria, lupine, or oats before corn did not increase the yield of continuous corn over native cover for green manure. Corn grown in the three-year rotation of peanuts, lupine, corn, oats, crotalaria, oats yielded four bushels more than the average for corn grown continuously or in any of the other rotations.

Yields of peanuts in the continuous crop and rotation experiment are given in Table 7. Peanuts grown in two-year rotations yielded 390 pounds per acre more than peanuts grown continuously. The average yield of

TABLE 5.—EFFECT OF FERTILIZER ON OATS GROWN ON NORFOLK LOAMY FINE SAND.

Fertilizer			Year										Average
N	P_2O_5 lbs./acre	K_2O	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	
							bus/acre						
21	25	20	15	11	8	48	52	52	23	18	17	21	27
42	50	40	25	15	23	73	63	58	28	22	20	31	36
63	75	60	26	14	26	89	62	61	30	27	26	39	40
21	75	60	26	19	26	71	62	54	32	27	21	33	37
42	75	60	25	16	22	72	62	53	28	29	22	33	36
63	75	60	26	14	26	89	62	61	30	27	26	39	40
63	25	60	17	10	16	60	61	45	20	17	15	20	28
63	50	60	24	14	21	72	65	49	27	22	20	30	34
63	75	60	26	14	26	89	62	61	30	27	26	39	40
63	75	20	20	10	22	67	47	41	17	17	18	25	28
63	75	40	20	15	23	81	59	13	28	22	19	33	34
63	75	60	26	14	26	89	62	61	30	27	26	39	40
L. S. D. (.05)			7	N.S.	10	13	8	11	7	4	3	9	
L. S. D. (.01)			10		14	17	11	14	10	5	4	12	

TABLE 6.—Effect of Rotations on Corn Grown on Ruston Fine Sandy Loam.

Rotation	Year 1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Ave.
	bus/acre											
Continuous corn:												
Corn only	65	63	66	17	55	59	28	66	66	85	70	58
Corn Crotalaria*	60	62	63	17	49	53	31	60	62	78	66	55
Corn lupines*	62	63	71	18	60	58	31	73	71	65	57	57
Corn lupines*	64	64	68	17	60	57	30	70	69	64	61	57
Corn oats*	69	64	68	22	56	62	34	72	75	80	43	59
Ave.	64	63	67	18	56	56	31	68	69	74	59	57
Two year:												
Peanuts native cover*												
Corn native cover*	66	69	70	22	55	51	31	55	63	69	68	56
Peanuts lupines*												
Corn velvet beans	66	24	70	24	60	55	35	57	65	72	75	58
Ave.	66	46	70	23	58	53	33	56	64	70	72	57
Three year:												
Peanuts lupines*												
Corn Crotalaria* lupine*	63	66	63	20	55	53	33	66	52	76	73	56
Corn Crotalaria*	63	64	70	19	54	61	31	63	70	70	69	58
Peanuts lupines*												
Corn oats*	59	73	73	21	60	60	38	66	68	80	77	61
Crotalaria* oats*												
Ave.	61	68	69	20	56	58	34	65	63	75	73	58
L.S.D. 5%	N.S.	6	6	5	N.S.	6	5	6	7	7		
L.S.D. 1%		8	N.S.	N.S.		8		9	10	10		

*plowed under as green manure

TABLE 7.—ANNUAL YIELDS OF PEANUTS GROWN ON RUSTON FINE SANDY LOAM AS AFFECTED BY VARIOUS ROTATIONS.

Rotation	Year										Average last nine years
	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958**	
	Lbs/acre										
Continuous peanuts:											
Peanuts native cover*	2180	1280	1280	680	960	700	1460	810	1910	1520	1180
Peanuts lupine*	2060	1470	1530	900	1270	740	1940	1350	2220	1770	1460
Peanuts oats*	1940	1670	1610	1040	1500	940	2060	1610	2480	1950	1650
Ave.	2060	1470	1470	870	1240	810	1820	1260	2200	1750	1430
Two year:											
Peanuts native cover*	2090	1820	2020	1470	1820	1040	2050	1580	2860	1820	1830
Corn native cover*											
Peanuts lupine*	1870	1790	1940	1260	1580	930	1960	1320	2600	2100	1720
Corn velvet beans											
Peanuts lupine*	1980	1960	2170	1640	1740	880	2150	1770	2750	2180	1920
Native cover*											
Ave.	1980	1860	2040	1460	1710	950	2050	1560	2740	2030	1820
Three year:											
Peanuts lupine*	2060	1930	2020	1720	1880	1060	2020	1710	2240	1980	1840
Corn crotalaria*											
Corn crotalaria* lupine*											
Corn, oats											
Crotalaria oats*											
Peanuts lupine*	2010	2140	2120	1920	1910	1160	2090	1980	2310	1920	1950
Ave.	2040	2040	2070	1820	1880	1110	2050	1840	2280	1950	1890
L.S.D. 5%	N.S.	322	378	400	256	170	260	300	460	320	
L.S.D. 1%		439	504	530	438	220	360	400	620	440	

*plowed under as green manure
**limed in spring of 1958

peanuts was 70 pounds per acre more for the three-year rotations than for the two-year rotations. When grown for harvest, continuous peanuts deplete the soil of calcium twice as fast as peanuts grown in a two-year rotation and three times as fast as peanuts grown in a three-year rotation. The average yield of peanuts was 110 pounds per acre higher for the three-year rotation corn, oats, crotalaria, oats, peanuts, lupine than for the three-year rotation peanuts, lupine, corn, crotalaria, corn with crotalaria, lupine. Since there is only one instead of two corn crops for the three years, it may not be the best rotation. When the two-year rotations are compared, peanuts made the highest yield in the rotation of peanuts, lupine, native cover. However, this is not the best two-year rotation for there is only one instead of two cash crops for the two years. Peanuts yielded only 90 pounds less in the two-year rotation of peanuts, native cover, corn, native cover and there are two instead of one cash crop for the two years. The nine year average yield of continuous peanuts with oats in winter for green manure was 470 pounds per acre higher than for continuous peanuts with native cover. Continuous peanuts with lupine for green manure made a nine year average yield of 280 pounds per acre more than continuous peanuts with native cover.

Fertility Experiment. Yields of corn with various rates of fertilizer are given in Table 8. Without fertilizer, the yield of corn dropped from 45 bushels per acre in 1949 to 26 bushels in 1959. With phosphate and potash high, increasing nitrogen from 0 to 100 pounds per acre increased the yield of corn from 46 to 65 bushels per acre for a 11-year average. With nitrogen and potash high, increasing phosphate from 0 to 108 pounds per acre increased the yield of corn from 55 to 65 bushels per acre for an average of 11 years.

Where nitrogen and phosphate were high, increasing potash from 0 to 60 pounds per acre increased the yield of corn from 47 to 65 bushels per acre for a 11 year average. While potash and nitrogen increased the average yield of corn 23 and 24 bushels per acre respectively, phosphate

TABLE 8.—EFFECT OF FERTILIZER ON CORN GROWN ON RUSTON FINE SANDY LOAM.

Fertilizer			Years											
N	P_2O_5	K_2O	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Ave.
lbs/acre			bus/acre											
0	0	0	45	53	51	18	32	31	23	26	37	37	26	34
0	108	60	48	60	59	26	55	32	31	38	45	53	56	46
25	108	60	58	68	67	28	64	43	32	57	61	64	66	55
50	108	60	71	73	74	24	65	53	28	66	70	84	74	62
100	108	60	85	71	73	25	69	50	32	75	70	92	75	65
100	0	60	74	65	66	20	46	56	32	56	52	83	53	55
100	27	60	60	61	72	22	56	59	32	62	67	89	62	58
100	54	60	81	75	76	25	62	46	35	72	60	90	75	63
100	108	60	85	71	73	25	69	50	32	75	70	92	75	65
100	108	0	75	64	48	19	36	38	24	59	57	66	36	47
100	108	15	82	63	67	21	58	48	30	72	66	88	67	60
100	108	30	78	62	69	22	62	51	30	74	71	91	71	62
100	108	60	85	71	73	25	69	50	32	75	70	92	75	65
L. S. D. 5%			10	13	13	5	10	7	9	11	10	10	10	
L. S. D. 1%			14	12	17	6	13	9	12	15	13	13	13	

TABLE 9.—EFFECT OF FERTILIZER ON PEANUTS GROWN ON RUSTON FINE SANDY LOAM.

Fertilizer			Years										
N	P_2O_5	K_2O	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Ave.
	lbs/acre												
							lbs/acre						
0	0	0	1950	2080	2220	1470	1550	1200	1610	1800	2190	2200	1830
0	48	40	1750	2420	2500	1820	1970	1350	2130	2150	1930	2350	2040
4	48	40	2040	2240	2510	1560	1980	1452	1840	2230	2130	2180	2020
8	48	40	1940	2600	2290	1740	2080	1272	1840	2160	2090	2140	2020
16	48	40	1970	2440	2280	1880	1990	1260	2150	1990	1790	2220	2000
16	0	40	2160	2440	2360	1720	1890	1428	2139	2350	2040	1520	2000
16	12	40	1890	2410	2310	1750	2050	1220	1880	2320	1740	1950	1950
16	24	40	2030	2450	2490	1800	1940	1400	1970	2310	2210	2090	2070
16	48	40	1970	2440	2280	1880	1990	1240	2150	1990	1790	2220	2000
16	48	0	1950	2440	2440	1780	1760	1380	2100	2210	2170	2230	2050
16	48	10	1980	2380	2400	1830	2010	1390	2120	2280	2150	2240	2080
16	48	20	1880	2410	2280	1830	1920	1350	1760	2260	1960	2160	1980
16	48	40	1970	2440	2280	1880	1990	1240	2150	1990	1790	2220	2000
			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	270	290	N.S.	380	
									366	N.S.	N.S.	N.S.	

reased the average yield only 10 bushels per acre. In the plots with- potash, most of the corn was lodged and the ears were small with a shelling percent.

Yields of peanuts with various rates of fertilizers are given in Table When peanuts are grown only once in a three-year rotation, it has been ssible to maintain yields for ten years without fertilizer. With fertilizer yield of peanuts was 120 to 250 pounds per acre more, but there was consistent increase in yield for any one fertilizer over another.

Yields of oats with various rates of fertilizers are shown in Table 10. thout fertilizer the yield of oats decreased from 49 bushels per acre in 50 to eight bushels per acre in 1957. With phosphate and potash at high rate, increasing nitrogen from 0 to 100 pounds per acre increased yield of oats from 34 to 67 for a seven year average. When nitrogen l potash were used at the high rate, increasing phosphate from 0 to 108 unds per acre increased the average yield of oats from 58 to 67 bushels acre. With nitrogen and phosphate high, increasing potash from 0 to pounds per acre increased the yield of oats from 52 to 67 bushels per e for a seven year average. With nitrogen at the 0 rate and phosphate l potash high, the yield of oats dropped from 57 down to 13 bushels r acre. Where nitrogen and potash is high and phosphate is at the zero e, the yield of oats remained high until 1956 and then decreased to 33 shels per acre.

Yields of soybeans with various rates of fertilizer are given in Table 11. ithout fertilizer the nine year average yield of soybeans was nine bushels r acre. When phosphate and potash were used at a high rate, increasing rogen from 0 to 32 pounds per acre increased the nine year average ld of soybeans from 15 to 21 bushels per acre. With nitrogen and tash at the high rate, increasing phosphate from 0 to 72 pounds per

TABLE 10.—EFFECT OF FERTILIZER ON OATS GROWN ON RUSTON FINE SANDY LOAM.

Fertilizer			Years*							
	P_2O_5	K_2O	1950	1951	1952	1954	1955	1956	1957	Ave
	lbs/acre									
						bus/acre				
0	0	0	49	39	30	19	25	11	8	26
0	108	60	57	36	41	20	46	22	13	34
5	108	60	72	57	49	29	56	24	28	45
0	108	60	72	74	43	36	64	75	50	59
0	108	60	53	73	82	56	72	66	64	67
0	0	60	64	69	48	44	70	76	33	58
0	27	60	49	68	48	50	73	71	56	59
0	54	60	48	61	65	36	66	70	54	57
0	108	60	53	73	82	56	72	66	64	67
0	108	0	40	58	73	38	55	52	50	52
0	108	15	43	73	82	32	66	62	65	60
0	108	30	44	72	89	59	74	74	61	68
0	108	60	53	73	82	56	72	66	64	67
L. S. D. 5%			19	13	20	16	15	20	13	
L. S. D. 1%			N.S.	17	26	22	21	27	17	

*Oats were killed by frost in 1953.

acre increased the nine year average yield of soybeans from 16 to 21 bushels per acre. Where nitrogen and phosphate were used at the high rate, increasing potash from 0 to 60 pounds per acre increased the nine year average yield of soybeans from 15 to 21 pounds per acre. These results show that nitrogen, phosphate, and potash each have about the same effect on the yield of soybeans.

TABLE 11.—EFFECT OF FERTILIZER ON SOYBEANS GROWN ON RUSTON FINE SANDY LOAM.

Fertilizer			Years*									
N	P_2O_5	K_2O	1949	1950	1951	1952	1953	1955	1956	1957	1958	Ave.
lbs/acre			bus/acre									
0	0	0	6	6	5	12	5	12	11	6	14	9
0	72	60	8	6	5	21	13	17	18	14	30	15
8	72	60	10	5	6	21	15	21	18	20	26	16
16	72	60	10	9	8	21	14	21	19	13	26	16
32	72	60	15	17	9	26	15	28	23	22	30	21
32	0	60	12	18	8	14	12	20	20	17	21	16
32	18	60	11	16	8	18	14	18	18	17	23	16
32	36	60	18	16	8	24	14	21	18	17	26	18
32	72	60	15	17	9	26	15	28	23	22	30	21
32	72	0	16	16	7	15	6	14	17	18	24	15
32	72	15	13	17	9	23	12	21	20	21	28	18
32	72	30	16	14	9	24	14	23	19	30	30	20
32	72	60	15	17	9	26	15	28	23	22	30	21
L. S. D. 5%			2	5	2	5	5	6	3	9	7	
L. S. D. 1%			2	7	2	6	6	8	4	12	9	

*Yields for 1954 not taken because of poor stand.

SUMMARY

Experiments were conducted for periods up to 12 years on Norfolk loamy fine sand and Ruston fine sandy loam to determine the effect of rotations and fertilizers on crop yields and on soil fertility.

On Norfolk loamy fine sand, peanut yields decline when grown continuously as compared to peanuts grown in rotation. For the last seven years on Norfolk loamy fine sand the average yield of peanuts was 560 pounds higher on the two-year rotations and 740 pounds higher on the three year rotations than when grown continuously.

Corn grown in two-year rotations averaged eight bushels more and in the three-year rotations 10 bushels more than corn grown continuously with no cover crop. There was a close correlation between the total rainfall for May, June, and July and the yield of corn. For the last five years, lupine following continuous peanuts made the lowest yield, probably because of disease common to both crops. When following peanuts, lupine should be grown only once in a three-year rotation. Lupine following continuous corn yielded as much as lupine grown in rotation. Increasing 8-10-8 fertilizer from 250 to 750 pounds per acre increased the yield of corn 13 bushels per acre for a 12 year average. When grown in rotation, the rate of fertilizer application required for optimum yields was approximately 750 pounds of 8-10-8 for corn and oats, and 200 pounds of 2-10-4 for peanuts.

On Ruston fine sandy loam the average yield of peanuts for the last nine years was 640 pounds higher on the two year rotations and 710 pounds higher on the three year rotations than when grown continuously with native cover. Growing continuous peanuts with lupine or oats increased the yield of peanuts 280 and 470 pounds per acre respectively over growing continuous peanuts with native cover. Corn yields were about the same for corn grown continuously and in two-year and three-year rotations.

Without fertilizer the yield of corn decreased from 45 bushels per acre in 1949 to 26 bushels in 1959. When 100 pounds of nitrogen, 108 pounds of phosphoric acid, and 60 pounds of potash per acre per year was used on the corn, the yield of corn was maintained and the average yield for the 11-year period was 65 bushels per acre.

When peanuts are grown only once in a three-year rotation it has been possible to maintain peanut yields for 10 years without fertilizer. With fertilizer, peanuts yielded 120 to 250 pounds per acre more, but there was no consistent increase in yield for any one fertilizer over another.

Without fertilizer, oats grown once in a three-year rotation decreased in yield from 49 bushels per acre in 1950 to eight bushels in 1957. With 100 pounds of nitrogen, 108 pounds of phosphoric acid, and 60 pounds of potash per acre, oats made a seven-year average yield of 67 bushels per acre.

Soybeans grown in a three-year rotation without fertilizer made a nine-year average yield of nine bushels per acre. With 32 pounds of nitrogen, 72 pounds of phosphoric acid, and 60 pounds of potash per acre, soybeans yielded 21 bushels per acre for a nine year average.

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Recent Progress In General Crop Production In Western Florida[1]

C. E. HUTTON AND M. C. LUTRICK[2]

Initial research was begun at the West Florida Station in the fall of 1948. Prior to that time the research on soils in western Florida consisted of experiments conducted on farms, in cooperation with the owners, by a Mobile Unit under the direction of the North Florida Station at Quincy. Due to the geographic location, distance prohibited extensive experiments by personnel from the Main Station at Gainesville. At that time, there was not a great deal of specific information on the chemical behavior or the availability of plant nutrients in these soils.

The soils in western Florida vary from deep sands to red and yellow fine sandy loam soils with sandy clay substrata. Geographically, they belong to the middle province or the Coastal Plain topography and essentially are a product of sea water sediments from the outwash plains of the Piedmont Plateau. They consist primarily of coarse to fine sand and clay with very little silt. The soils high in iron and aluminum, have a low phosphorus content and a high phosphorus fixing capacity, are medium in their potassium bearing mineral and, for the most part, have an ample supply of the minor elements. Many of the soils are high in manganese. The bulk density of the sandy clay substrata approaches 1.6 and being massive in structure impedes root development into the subsoil area. Colloidal alumina also restricts root development.

The object of the original research, started in 1948, was to determine quantities and ratios of plant nutrients, management practices and adapted crop varieties which would allow the grower to produce a maximum economic yield of the major crops. Concurrently primary, secondary, and minor nutrient studies and variety trials for most of the major agricultural crops grown in western Florida were initiated. This paper contains data to show some of the progress made up to the present time.

CORN

Corn yields were relatively low at the beginning of this period for several reasons. First, open-pollinated varieties were grown by almost all of the growers, although some of the hybrid varieties were available at that time. Second, spacing of the corn plants in the drill was from 36 to 42 inches in 38 to 40 inch rows. Third, low analyses fertilizers were used in small quantities with little or no nitrogen sidedressing. A part of the fertilizer and nitrogen usage was an outgrowth of lack of supply during the war years and even at this particular time the amount of nitrogen available was not large. However, most growers grew large acreages of corn at low fertilizer rates rather than small acreages at a higher fertility level.

A five level NPK factorial with two levels of lime was initiated in the spring of 1950 and continued for seven years to determine the fertility

[1]Florida Agricultural Experiment Station Journal Series, No. 1027.

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requirements on a Red Bay fine sandy loam. Reported in Table 1 are the pounds per acre of N, P_2O_5, and K_2O which gave maximum net return for corn production. The low yields reported for 1952, 1954 and 1955 were due to a poor distribution of moisture during and following tasseling. Moisture distribution in these years reduced the response to nitrogen. The response to phosphorus was extremely high in years of ample rainfall and, in general, the response to potassium was good every year. The yield responses reported are dependent on the amount and distribution of rainfall during the critical period. In normal years, the rate of increase per unit application of nitrogen and phosphorus was much larger than for potassium, but there was a consistent increase to potassium fertilization even in years when rainfall distribution was poor. Hence, the rate of K_2O required to give a maximum net return is a result of consistent yield increases to potassium rather than to the magnitude of these increases.

TABLE 1.—POUNDS PER ACRE OF N, P_2O_5 AND K_2O WHICH GAVE MAXIMUM NET RETURN FOR CORN

Year	N	P_2O_5	K_2O	Yield
1950	81	228	84	73
1951	87	249	71	91
1952	0	30	60	25
1953	54	189	86	65
1954	0	30	77	52
1955*	30	120	90	50
1956*	60	180	60	83
1957*	60	60	30	62

*Estimated from data

One set of plots of the above experiment was changed in 1955 to study the residual effect of phosphorus and potassium on corn production and these data are reported in table 2. This table reports the annual applications of P_2O_5 and K_2O during the 1950-54 period and the average of five replications for the 1955-59 period. Each figure in the table represents an average of 25 yield observations for each treatment. Incorporated in the study was the response to phosphorus where no additional phosphorus, 30 pounds of P_2O_5, and 60 pounds of P_2O_5 were applied annually to all P_2O_5 residual levels. In the potassium study, the residual effect of potassium was studied where no additional potassium was added and where 30 pounds of K_2O were applied uniformly to all K_2O residual levels. In each of these studies ample nitrogen and potassium was applied on the phosphorus residual study and ample nitrogen and phosphorus was applied on the potassium residual study. Except for 1957, when maximum yields were limited to approximately 60 bushels, rainfall distribution seemed adequate for corn production and good yields were obtained. In comparing these data it will be seen that the response to the residual phosphorus during 1955-1957 was extremely good where no additional phosphorus was added. Even where 30 or 60 pounds of P_2O_5 were applied annually, an excellent residual response was obtained up to the fourth or fifth residual level. This indicates that phosphorus applied to the soil would be available to succeeding crops over a relatively long time. Although the production of corn was good on plots which had never re-

TABLE 2.—AVERAGE CORN YIELD FROM RESIDUAL P_2O_5 AND K_2O STUDY FOR 1955-59 PERIOD*

Residual Level	Uniform Annual P_2O_5 Application**						Uniform Annual K_2O Application***			
	0		30		60		0		30	
	L	UL	L	UL	L	UL	L	UL	L	UL
1	21	18	53	42	61	53	65	60	69	63
2	41	33	60	52	67	56	68	62	73	67
3	58	46	66	60	68	64	71	66	72	66
4	70	55	71	64	78	63	72	65	76	67
5	77	68	74	69	80	72	72	67	70	68

*Pounds of K_2O per acre corresponding to levels 1, 2, 3, 4 and 5 were 0, 15, 30, 60 and 120, respectively. P_2O_5 rates for comparable levels were double those for K_2O.

**All plots received 120-0-120

***All plots received 120-240-0

ceived potassium fertilization, there was a slight response to residual potassium when no additional potassium was added during the study. When 30 pounds of K_2O per acre were applied annually to the various residual levels, there was no significant response to potassium from the residual period.

While the above reported studies were in progress, corn was grown at high fertility levels under irrigation on the best agricultural soils in the area to determine maximum potential yields. From the above studies, it was evident that moisture distribution was often the main limiting factor in corn production. Even with ample moisture and high rates of the major nutrients, corn yields were limited to a maximum of about 110 bushels per acre. In an attempt to raise the yield above this figure, studies were made where organic matter was applied at high rates, and where lights were provided for an additional five hours daily during a six weeks period during and following tasseling. None of these methods have produced corn yields above the 110 bushels per acre level. From these data, it is speculated that corn varieties with their present genetical makeup are the main limiting factor in the production of corn yields above this ceiling.

Dates of Planting, Population and Nitrogen Levels. In this study, Dixie 18 corn was used with all plots receiving 700 pounds of 4-12-12 per acre. As shown in Table 3, corn should be planted by the first of April each year. Another factor affecting corn yields, not indicated in the table, is that of percentage germination. Poor germination was obtained for the March 1 planting because of low temperature and wet soil and for April 1 because of dry soil conditions.

A population of 5,000 stalks limits corn yields to 50 to 60 bushels per acre. Yields increased consistently up to 12,500 stalks per acre with yields of 65 to 75 for 7,500, 75 to 80 for 10,000 and 85 to 90 for the 12,500 stalks per acre. There was no further appreciable increase for the 15,000 stalk population.

The low nitrogen level was 60 pounds and the high nitrogen was 120 pounds of N per acre. When the plant population was no more than 7,500

TABLE 3.—The Influence of Dates of Planting, Population and Nitrogen Level on the Yield of Corn in 1958 and 1959.

	Population																			
	5,000				7,500				10,000				12,500				15,000			
	1958		1959		1958		1959		1958		1959		1958		1959		1958		1959	
Planting	LN	HN	LN	HN	LN	HN	LN	HN	LN	HN	LN	HN	LN	HN	LN	HN	LN	HN	LN	HN
March 1	46	54	48	46	58	65	63	60	73	79	74	75	83	82	81	84	88	94	82	86
March 15	53	55	51	50	72	74	65	69	75	84	70	77	77	92	77	87	81	101	82	87
April 1	65	75	54	64	79	79	61	73	78	94	71	74	81	89	75	86	88	94	75	85
April 15	57	62	46	48	74	72	55	61	82	80	65	65	87	84	61	68	88	96	66	73
May 1	47	50	26	28	62	65	32	34	70	60	31	42	77	75	40	33	73	77	29	39

LN = Low Nitrogen
HN = High Nitrogen

TABLE 4.—Pounds Per Acre of N, P_2O_5 and K_2O Which Gave Maximum Net Return for Peanuts

Year	N	P_2O_5	K_2O	Yield
1950	0	153	15	1577
1951	0	183	15	1206
1952	0	168	15	1827
1953	0	126	15	1655
1954	0	120	15	1700

stalks per acre, yields were not influenced by nitrogen level. At higher plant population, the high nitrogen level increased yields above the 60 pound per acre rate. This indicates that the optimum rate of nitrogen is somewhere between 60 and 120 pounds per acre.

The ear height increases with each succeeding date of planting. The amount of lodging increased with planting dates, being slight on March 1 and 15, medium on April 1 and severe on the April 15 and May 1 planting dates. There were some indications that the 12,500 and 15,000 plants per acre stands lodged worse than those with lower plant populations.

The best general recommendation is 10,000 stalks per acre planted between March 15 and April 1 using between 60 and 120 pounds of N per acre.

PEANUTS

A five level NPK factorial with two levels of lime was initiated in 1950 to study the production of peanuts on a Red Bay fine sandy loam. The pounds per acre of nitrogen, phosphorus and potassium which gave maximum net returns for peanuts is presented in Table 4. From this table, it will be seen that there was no response to nitrogen for any year, that the response to P_2O_5 was extremely good in all years and that the response to K_2O was relatively small every year. The peanut is a difficult crop to study from a fertility standpoint. Unlike the grasses, it does not respond to fertilizer applications when the residual soil fertility is medium to good. In this study, potassium decreased nut yields every year when more than 15 pounds of K_2O were applied. Although the response to phosphorus was good, the highest rate of phosphorus also tended to reduce nut yields. The response to limestone on peanuts was positive for most years amounting to 160 to 200 pounds per acre as an average for all treatments.

Additional work on other experiments with peanuts during and following the period reported above has not consistently increased peanut yields over the years. The use of management methods with herbicides at optimum fertility levels has not consistently increased nut yields above 2000 pounds per acre.

Growers in this area have grown peanuts for many years and, in general, their management practices are good. Fertility-wise, at the beginning of this reporting period, they were using more nearly the proper amounts of fertilizer for peanuts than they were for corn and, consequently, increases in yields have been due to management practices, addition of limestone in their fertility program and planting of better varieties which have been made available to them.

SMALL GRAINS—SOYBEANS

At the beginning of this reporting period, oat yields were low because of disease. No wheat was grown in this area at that time and very few acres of soybeans were grown. New varieties of oats released by the North Florida Station in the early 1950's increased the interest in small grains. As a result of new wheat varieties and a study of their yielding ability in variety trials, considerable acreages of wheat were planted in the early 1950's. Because of the ability of growers to produce a second crop on small grain acreage, and since soybean varieties were available which would

produce economic yields, the acreage of soybeans in western Florida has increased rapidly during the past several years. Soybeans were first grown in Escambia County, Florida, and adjacent Alabama areas. During recent years the acreage has expanded eastward through Santa Rosa and Okaloosa Counties. Soybeans are considered an important crop at the present time and there is every indication that it will become more important. Other work with small grains and soybeans indicate that the response to fertilizer applications is not as striking as with either corn or peanuts so far as phosphorus is concerned and response to nitrogen is not as great as with corn. However, there are indications that soybeans will require higher minimum levels of soil potassium than corn.

To determine the response of wheat and soybeans to varying residual amounts of phosphorus and potassium, a five level P_2O_5 and K_2O residual experiment was used. This experiment had received from 0 to 240 pounds of P_2O_5 and 0 to 120 pounds of K_2O (see table 5) annually from 1950-57.

TABLE 5.—RESPONSE OF WHEAT AND SOYBEANS TO RESIDUAL P_2O_5 AND K_2O

Soybeans—1958

Residual Level	K_2O		P_2O_5	
	Limed	Unlimed	Limed	Unlimed
1	29*	25	18	17
2	33	29	33	26
3	36	31	39	31
4	38	32	43	35
5	39	32	43	40

*Each figure represents average of 25 observations

Wheat

Residual Level	K_2O				P_2O_5			
	1958		1959		1958		1959	
	L	UL	L	UL	L	UL	L	UL
1	26	25	7	6	10	9	6	5
2	33	30	10	9	25	21	9	6
3	33	32	10	9	31	27	11	10
4	36	32	13	11	34	32	13	12
5	35	32	12	11	32	32	14	13

Ample N was applied to wheat for good crop yield

Residual Level	Annual Application in Lbs./A 1950-57	
	P_2O_5	K_2O
1	0	0
2	30	15
3	60	30
4	120	60
5	240	120

These data in Table 5 show a residual response for P and K for both wheat and soybeans. The response to P_2O_5 is more marked than for K_2O in every instance. Excellent yields of both wheat and soybeans were grown at the higher residual levels when moisture was favorable. Wheat yields in 1959 were low due to a prolonged drought in May 1959.

SUMMARY

A review of the progress made in general crop production is presented for the period 1948 to 1959.

Yield trends and changes in crop management are discussed. The progress made is attributed to increased fertilizer usage and better adapted plant varieties.

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Progress in Research On Field Crops In Southern Florida, 1939-1959[1]

VICTOR E. GREEN, JR.[2]

The beginning of fiscal year 1939 marked the start of the second half-century of research of the Florida Agricultural Experiment Stations. Coincidentally, organizational meetings of the SSSF were held January 12, March 27 and April 18, 1939. State Projects 203, 204, 205, and 207 were already begun. During the first decade of the first fifth-century of our society, the dissemination of research results in south Florida was made chiefly by publication in the Annual Reports of the Agricultural Experiment Station. Free use has been made of them in the development of this paper and a

[1]During the period covered by this paper the following research workers contributed materially to the knowledge on field corn and small grains: Dr. F. T. Boyd, from February 14, 1938 to June 30, 1941; Dr. Roy A. Bair, from October 1, 1941 to September 30, 1950; Dr. Raymond H. Webster, December 1, 1950 to February 29, 1952. The author's service began on June 25, 1951. Dr. Boyd returned and has served since January 1, 1953 at the Plantation Field Laboratory. Dr. Albert E. Kretschmer has served at the Everglades Station and the Indian River Field Laboratory since July 1, 1952. Dr. W. J. Wiser, Research Agronomist, Corn and Sorghum Section, CRD-ARS-USDA was assigned at Belle Glade from July 1, 1956 to June 30, 1959.

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bibliography of the published work is included. A number of releases containing the findings of research in south Florida on field crops have appeared as Everglades Station Mimeo Reports.[3]

Dr. Wilmon Newell aptly stated the problem facing the agronomists in south Florida when he wrote in 1939,[4] "Florida's diversity of soils, crops and climatic conditions has led to a complex agriculture widely different in the several sections and distinctly unlike that of most other states, a circumstance that has required extensive experimentation for successful development and maintenance. Many of the State's agricultural problems are exclusively its own and it has been necessary to depend on localized research because of lack of application of experimental findings developed elsewhere. It is of interest to note the foresight indicated in this connection in the opening paragraph of Bulletin 1, issued in 1888 by the Director and constituting the first official stations publication, which reads: "The Director of the station is not without a deep sense that his work is, to a great degree, a peculiar one, owing to the latitudinal and climatic characteristics of Florida. Other stations have helps from correspondent and analagous surroundings that afford mutual advantages in station work. But the Florida station, located on a peninsula between ocean and sea, alone, must work out its own material.' "

During the past 20 years concerted attempts have been made through statewide and regional uniform variety tests and a free interchange of breeding material, but we still do not have a variety of a field crop that can be recommended over the latitudes of Florida. Boyd,[5] after reviewing the many reports of field crop failures, was the first to begin a crop improvement program. He wrote, "Since past experience at this station has shown that the small cereal grains cannot be grown profitably, greatest attention has been given to developing the corn grain crop."

FIELD CORN

Although each succeeding agronomist at Belle Glade tested Boyd's hypothesis, each one continued the corn improvement program. A graphic presentation of the results of that program appears as Figure 1. A detailed summary of that work has been published (8).

Much of the research and thinking on corn culture has been directed toward the production of shelled, dry corn (elevator corn). There is probably no reason for this other than the ease of reporting yields as bushels of U. S. No. 2 grain. There are no elevators in the area and ranchers are not equipped for feeding shelled grain. Most of the corn is harvested by snapping the ears along with the inner husks and is fed after grinding in a hammer mill. Weather conditions, weed growth, and insect attacks all threaten the yield of grain from the milk stage to maturity (11).

During the past three years, work has been directed toward a better utilization of the subtropical varieties. These corns are naturally taller, leafier, and longer seasoned, and the foliage remains green almost to

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[3]Everglades Station Mimeo Reports
Field Corn: 55-4, 56-2, 57-5, 58-10 and 59-7
Sorghum, Sorgo and Millet: 58-12, 59-4, 60-1 and 60-2
Popcorn: 60-5.

[4]In Agri. Exp. Sta. Golden Anniv. Report, p. 6. 1938.

[5]Loc. Cit. Project 204, Grain Crop Investigations, p. 160.

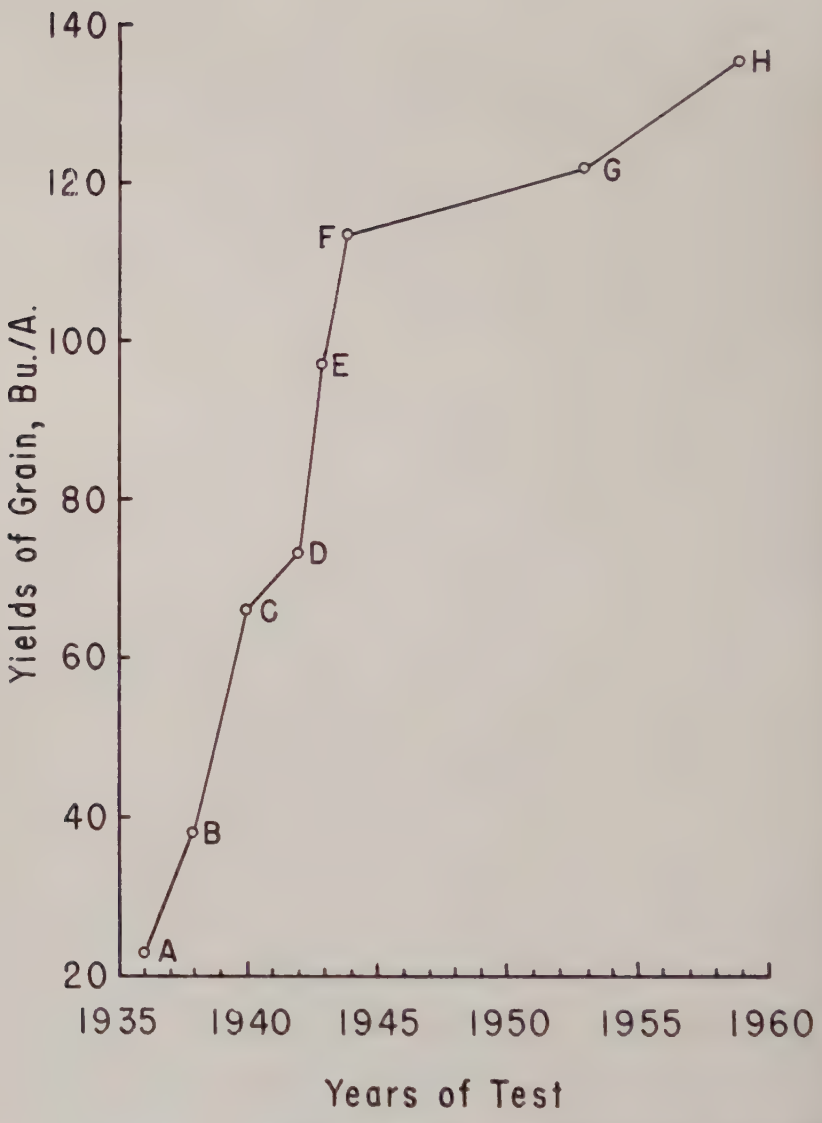

Figure 1.-Progress in corn research as reflected by increasing yields from 1936 to 1959. The maximum record yields and reasons for them are: A, Open-pollinated varieties; B, improved OP varieties; C, first hybrid varieties; D, Mayorbela, from Puerto Rico; E, Big Joe Synthetic variety; F, improved spacing and plant populations; G, improved tropical crosses; H, well adapted Cuban hybrids and improved cultural methods.

harvest. These are some of the characteristics that are sought in the search for an ideal forage crop. The data collected during these tests showed that harvesting the entire plants gave 460 percent as much protein and 550 percent as much feed as harvesting a 60-bushel grain crop. Even snapping the "roasting ears" in the soft dough stage along with the inner

TABLE 1.—THE YIELD AND PROTEIN CONTENT OF VARIOUS COMPONENTS OF ADVANCED STAGE CORN STALKS (CORNELI 54). BELLE GLADE, FLORIDA. 1957.[1]

Component	Dry Matter %	Percentage of total weight	Yield per acre pounds		Protein percent dry basis	Protein/ acre dry basis, lbs.
			fresh	dry		
Tassels	59	1	290	170	6.56	11
Stalks	22	34	26,660	5865	5.51	324
Leaves	30	24	13,940	4180	10.50	439
Ears, slipshucked	44	41	16,435	7230	7.79	570
Total		100	57,325 28.7 tons	17,445 8.7 tons		1344

[1]Planted February 8; harvested June 8, 1957 in soft dough stage.
The average protein content of entire plants—8.5%.

husks gave almost twice the protein per acre on a dry basis when compared to the dry grain from such plants. See Table 1.

When Corneli 54 was in the soft dough stage, the green leaf yield alone was almost two and a half times as high in protein per acre on the dry basis as the 60 bushels of dry grain expected from the crop. In fact, the leaves alone could have been harvested and ensiled, or thermally dehydrated and the ears thrown away with a higher yield of protein per acre than the grain crop. See Table 2.

The merits of corn silage are well known and need no justification. On

TABLE 2.—THE YIELD AND PROTEIN CONTENT OF CORN LEAVES AND STALKS AS RELATED TO POSITION ABOVE AND BELOW THE EAR. (CORNELI 54). BELLE GLADE, FLORIDA. 1957.[1]

Component	Dry Matter %	Percentage of total weight		Yield per acre pounds		Protein percent dry basis	Protein per acre dry basis, lbs.
		Fresh	Dry	Fresh	Dry		
Leaves							
Above ear	34	10	12	2940	940	14.70	138
Below ear	28	13	20	3640	1640	12.25	201
Total		23	32	6580	2580		339
Stalks							
Above ear	18	14	9	3920	635	4.55	29
Below ear	27	63	59	17,600	4840	6.91	334
Total		77	68	21,420	5475		363
Subtotals							
Above ear		24	21	6760	1575		157
Below ear		76	79	21,240	6480		535
Total		100	100	28,000	8055		702
				14 tons	4 tons		

[1]These figures do not reflect the yields of the ears (12,570 lbs. fresh weight or 5,530 lbs. dry weight) with an average protein content of 7.8 or 432 pounds of protein per acre. The total acre yields including the ears were 40,570 lbs. (20.3 tons) green or 13,585 lbs. (6.8 tons) dry. The total protein content of an acre of corn is 702 + 432 = 1134 pounds. All leaves were still green and the ears were in the soft dough stage.

the organic soils, large tonnages of stems and leaves can be grown and harvested successfully almost every year, while a satisfactory harvest of grain is not always assured. These two factors favor the use of entire field corn plants.

SORGHUM, SORGO, AND MILLET

These crops have been grown at the Everglades Station every year since its founding with varying degrees of success. The sorghum work has been directed toward finding varieties that have open, sprangly heads that will not mold upon ripening, awned glumes or other characteristics that will obviate the very important problem of devastation by birds, and varieties that are indifferent to day length. Recently such varieties have been found and will be described in a forthcoming station bulletin (12).

Many varieties of sorgo are available for planting in south Florida for silage production. The sweetest varieties are Tracy and Wiley. The widespread use of sorgo as silage material awaits only the acceptance by ranchers of the practice of putting up silage.

The data in Figure 2 show the relation of the age of sorghum, sorgo, and millet in weeks to the yield and quality of those crops. From eight to twelve weeks the protein percentage of the forage decreases markedly, while the yield of forage shows a decided increase. This increase in yield offsets the protein decrease as shown by the increase in crude protein per acre.

Every planting of Gahi 1 variety of millet has produced a successful crop of forage and is highly recommended for preservation as winter feed. Yields of Gahi have exceeded those of Starr by 50 percent, on the average.

POPCORN

Tests were begun in 1952 to determine if popcorn could be produced profitably in the Everglades. Data collected over the past eight-year period showed that profitable yields of high quality grain could be produced by planting early in February, good insect and weed control measures, and promptly harvesting the grain as soon as the moisture therein had dropped to about 25 percent. Spraying for leaf blight may be necessary each year. Late maturing varieties (requiring in excess of 115 days) gave higher yields of popcorn with greater expansion ratios. Premature drying caused by Northern leaf blight was detrimental to expansion of the popped product. Grain grown in south Florida when dried properly to prime moisture content would, upon popping, give expansion ratios up to 40:1. Normal expansion figures vary from 31:1 to 39:1. The popped corn was excellent for taste, tenderness, and flakiness (13, 14, 15).

RICE

An intensive program of rice research progressed from 1950 to 1958. For the duration of state project 680, the U.S.D.A. Uniform Rice yield nursery and the world collection of rice varieties were grown. Many advances were made, but the most notable were in the province of phytopathology. Epiphytotics of the common rice diseases advanced the knowledge of the resistance of the common varieties to the extent that many of

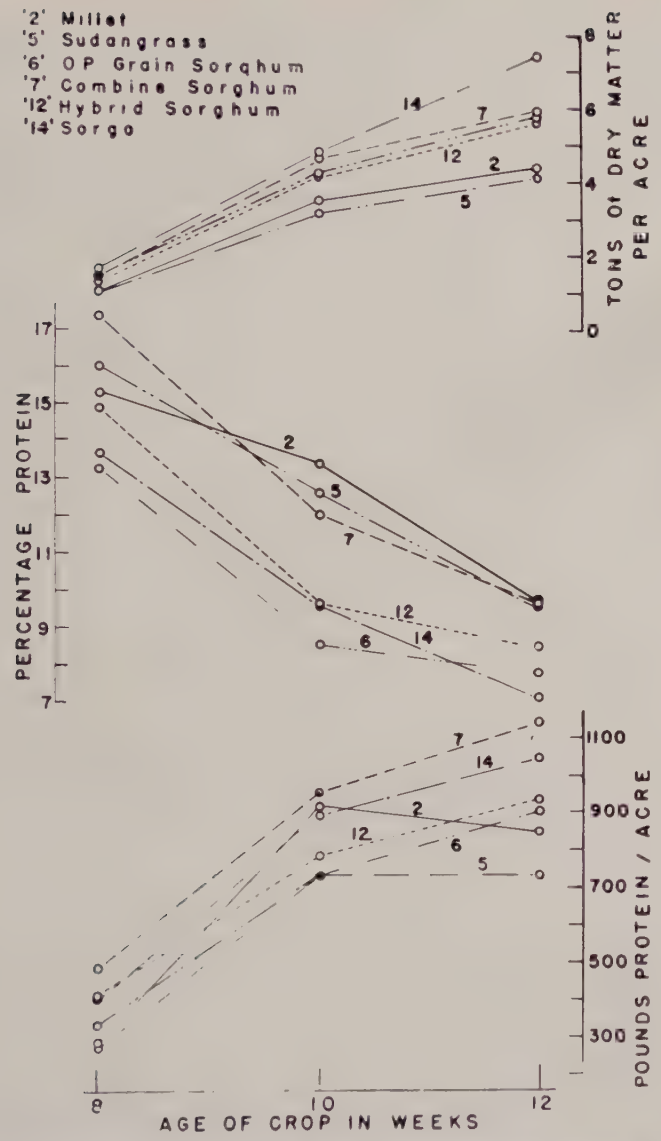

Figure 2.—The Relationship of the Age of Sorghum, Sorgo and Millet in Weeks to the Yield, Protein Percentage and Protein per Acre of the Forage. Belle Glade, Florida. 1958.

the varietal descriptions need changing. A review of the fungus diseases of rice in Florida has been published (22).

It was in the Everglades Experiment Station rice plots that the virus disease "Hoja Blanca" or white leaf first made its appearance in the United States. A complete story of its discovery and eradication appeared in the Rice Journal (24).

The National Rice Uniform Yield Test was grown for five years at

TABLE 3.—THE AGRONOMIC CHARACTERISTICS OF NAMED RICE VARIETIES GROWN AT THE EVERGLADES EXPERIMENT STATION OVER THE FIVE YEAR PERIOD 1953-1957.

Maturity Group and Variety	C. I. No.	Grain Type[1]	Avg. Date Maturity[2]	Seeding to Maturity	Avg. ht. culm.	Years grown	Mean yield	Comparable yield[3]
				Days	In.	Yrs.	Lbs.	%
EARLY:								
Cody	8642	S	Aug. 5	127	36	5	2560	82
Colusa	1600	S	Aug. 6	128	37	5	2860	91
Zenith	7787	M	Aug. 7	129	44	5	3230	103
Magnolia	8318	M	Aug. 5	127	45	5	2805	90
Early Prolific	5883	M	Aug. 9	131	43	5	4090	131
Lacrosse	8985	M	Aug. 12	134	44	5	3460	111
Nato	8998	M	Aug. 5	127	41	5	3640	116
Prelude	8311	L	Aug. 17	138	46	3	3675	117
CP 231	8993	L	Aug. 11	133	37	5	3350	107
Century 52	9002	L	Aug. 13	134	42	3	2480	79
Rexark	8644	L	Aug. 17	138	41	5	2405	77
MIDSEASON:								
Asahi	8312	S	Sept. 1	154	28	3	3400	109
Caloro	1561-1	S	Aug. 27	149	31	5	2025	65
Kamrose	8314	M	Aug. 31	153	43	3	2820	90
Arkrose	8310	M	Aug. 31	153	44	5	3345	107
Blue Rose	2128	M	Sept. 10	162	45	4	2785	89
Blue Rose 41	8317	M	Aug. 30	152	44	2	2035	65
Calrose	8988	M	Aug. 26	148	32	5	2075	66
Nira	2702	L	Aug. 25	147	50	5	2730	87
Sunbonnet	8989	L	Aug. 21	143	47	5	3760	120
Blue bonnet	8322	L	Aug. 22	144	48	5	3535	113
Bluebonnet50	8990	L	Aug. 23	145	44	5	3365	108
Imp. Bbt.	8992	L	Aug. 23	145	43	5	3425	109
Fortuna	1344	L	Aug. 22	144	48	5	3215	103
Toro	9013	L	Aug. 22	144	44	5	3595	115

[1]Short, medium or long.
[2]Average date sown is March 31; earliest March 27 and latest April 16.
[3]Percent of the mean of the 25 varieties grown the entire period for the actual years each variety was grown. (3130 lbs./A.)

Belle Glade. A summary of the agronomic characteristics of the released varieties in those tests is shown in Table 3. High yields were not directly associated with parentage, station of origin, disease resistance, length of growing season, grain length, plant height, or lodging.

As a part of the project, a bibliography of the culture of rice on organic soils was prepared and published (20), (21). The use of rice as a soil conservation measure was outlined (17) and a contribution to the iron nutrition of rice on peat soils appeared (21), (23).

OATS AND RYE

During the early work on oats and rye, hundreds of varieties were tested at Belle Glade for adaptability. Later, the effort has consisted chiefly of cooperative testing under Bankhead-Jones Project 287 and Hatch Project 783. Observations at Belle Glade have aided materially in the testing of strains and crosses in the state small grain improvement programs.

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Progress In Research On Shade Tobacco Disease Control, 1922-1959[1]

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INTRODUCTION

Research on control of diseases of shade-grown cigar-wrapper tobacco began in 1922 with the establishment at Quincy of the Tobacco Experiment Station, later expanded and re-named the North Florida Experiment Station. Since shade tobacco has kept its position of importance in north-central Florida, research on diseases of this crop has continued to be a major part of the tobacco program at this Station.

Methods found most useful in combating shade tobacco diseases include rotation, chemical treatments applied to soil or plant, and breeding for resistance. Breeding for disease resistance and other important characters of tobacco, including shade tobacco, in Florida is reviewed in another paper presented at this meeting (1).

Four diseases which have received most attention, and their causal organisms, are as follows:

Black shank (*Phytophthora parasitica* Dastur var. *nicotianae* Tucker)
Blue mold (*Peronospora tabacina* Adam)
Root-knot (*Meloidogyne spp.*)
Nematode root rot (*Pratylenchus spp.* and others)

Progress in research on control of these diseases is reviewed in this paper.

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BLACK SHANK

Black shank first appeared in Florida about 1915 and was first identified in 1922 (14). Shade tobacco varieties grown from 1915 to 1930 included slightly resistant Big Cuba, followed after 1923 by highly susceptible Connecticut Round Tip.

The earliest attempt at control (16) was made in 1922 by a grower who treated a 13-acre field with steam. A good crop of tobacco was produced that year, but some signs of the disease appeared in part of the field before the end of harvest. This part was steamed again in 1923 but became re-infested by water-borne inoculum from the other part, in which black shank appeared early in the season. Steaming proved to be too expensive, considering that it was effective for only one year.

Chemical treatments of the soil in the row were tested in 1924 and 1925 (16). Inoculated sulfur at 360 pounds per acre and Semesan at 80 pounds delayed the appearance of the disease. Land plaster (calcium sulfate) at 600 and 1,200 pounds appeared to aggravate the disease.

Infested fields which had been planted to corn and other immune crops for as long as five years remained infested (16). Thus, rotation was impractical as a means of control as long as a highly susceptible variety such as Round Tip was grown. Growers were forced to abandon infested fields, and move shades to new land, using cotton cloth instead of wood laths to provide shade. Heavy losses were frequently incurred during the first season in which the disease appeared.

Breeding for resistance to black shank proved to be the best approach to control. A selection from Big Cuba was moderately resistant, but inferior in quality. The best of several crosses having Big Cuba as a parent was No. 301, which resulted from a cross between selections of Big Cuba and Little Cuba. No. 301 had satisfactory resistance, yield, and quality (15). It was grown commercially for several years, especially in the 1930's.

The variety Rg was derived from a single surviving plant in a row of Round Tip grown in 1929. Its progeny had little resemblance to Round Tip, and it is believed to have originated from a misplaced seed of some other line. It had high resistance and good quality (3), and was the predominant commercial variety for some 20 years.

Dixie Shade, released in 1953, was derived by selection from RK 25, which was received from the United States Department of Agriculture. The pedigree of RK 25 was T. I. 706 x White Stem Orinoco, backcrossed to No. 400. Dixie Shade was slightly more resistant to black shank than Rg, and had certain other advantages (9). By 1955 it had become the predominant commercial variety.

Breeding is in progress, using breeding stocks which are apparently immune to black shank. Outstanding among these is Licey, originally collected in the Dominican Republic by E. G. Beinhart and received by the North Florida Experiment Station from the United States Department of Agriculture.

Incidence of black shank is directly related to soil pH (11). As measured by the black shank index (relative amount of root damage) of resistant varieties, and by mortality of susceptible varieties, incidence increased with soil pH from 5.0 or below to about 5.7; from 5.7 to 6.0 or above incidence remained fairly constant. Sulfur was used to lower the original pH of 5.2, and hydrated lime was used to raise it. Another ex-

periment is in progress to study the effects of adjusting pH from 6.0 to various lower levels on incidence of black shank and on yield and quality of the crop. Incidence of black shank is related also to soil texture. Field observations show that black shank is most severe on so-called heavy soils and least severe on light soils. The moderately susceptible Connecticut variety No. 49 has been grown on sandy soil in Madison County, or in new locations in Gadsden County.

Varieties resistant to the stem-rot phase of black shank are susceptible to leaf spot caused by the same fungus. Leaf spot occurs during warm, rainy weather on lower leaves which become inoculated with infested soil.

The resistance of varieties such as Rg and Dixie is such that they seldom show more than 5 percent of the plants dead or severely stunted by black shank, usually much less. This level of resistance, together with the common practice by growers of two-year rotation, is sufficient to keep losses to an acceptable minimum.

BLUE MOLD

Blue mold appeared in the shade tobacco area in 1921, again in 1931, and every year since then. Earliness in appearance and the severity of the disease in plant beds are related to January temperatures (12). Following a warm January, the disease commonly appears in February, reaches nearly all beds, and causes considerable loss of plants and delay in transplanting in beds not properly treated. Following a cold January, the disease may appear several weeks later and cause very little damage.

Attempt to control blue mold by sanitation, sunshine, and aeration proved inadequate. Good control was obtained by spraying with cuprous oxide in a cotton seed oil emulsion (12), and excellent control was obtained by vapor treatment with benzol or paradichlorobenzene (17). A more satisfactory treatment was obtained by spraying with ferbam (4). Spray and vapor treatments were rather expensive and laborious.

Dust treatments based on dithiocarbamates were much more satisfactory than sprays, because they required less labor and equipment. Ferbam 15 percent dust was largely replaced about 1948 by zineb 6.5 percent dust (5), which is still in use. Zineb in inorganic diluents is more effective than in organic diluents.[3]

Maneb 3.5 percent dust is still more effective under critical conditions, but has a smaller margin of safety.

Blue mold has occurred sporadically in fields, occasionally causing severe reduction in crop value. In a few extreme cases, the plants have been cut off a few inches above the soil, and suckers have been allowed to grow and produce a new crop of leaves.

Severity of blue mold in fields is related to severity in plant beds, because it affects the amount of inoculum carried in seedlings and blown by wind. The disease is likely to appear in fields under damp conditions when the night temperature falls below about 65 degrees F. Growers often withhold irrigation during dry, cool weather to avoid aggravating blue mold.

In limited comparative tests, zineb 6.5 percent dust applied twice a week controlled blue mold in the field. Growers usually make one applica-

[3]This and certain other items for which no reference to source is given have been taken from Florida Agricultural Experiment Station Annual Reports.

tion a week of fungicide in combination with insecticide, and one of fungicide alone. This is continued from transplanting until the danger of cool weather is past, usually about the latter part of May.

Late transplanting decreases the hazard of blue mold in the field, by reducing the length of time after transplanting during which weather conditions may be favorable for blue mold development. Most growers, nevertheless, consider that early transplanting is more favorable to high yield and quality, and they prefer to take the added risk of blue mold, relying on zineb dusting for control.

Commercial varieties differ considerably in susceptibility. Rg and Dixie Shade are less susceptible than Connecticut 49. Magnolia, released in 1958 (10), appears to be intermediate.

Breeding for blue mold resistance is in progress, using breeding stocks furnished by the United States Department of Agriculture. Some advanced generations of crosses with Florida varieties show indications of blue mold resistance, and wrapper type and quality, combined with black shank resistance. Resistance at even a moderate level could effect considerable savings in cost of fungicide treatments.

ROOT-KNOT

Root-knot has long been recognized as potentially one of the most serious diseases of cigar-wrapper tobacco.

Various cultivated crops and native weeds and grasses were tested in two-year rotations with tobacco (8). Six-year average results gave comparative root-knot indexes of the tobacco crops as follows:

Very low index
- Coffeeweed (*Emelista tora* B. and R.)
- Texas millet (*Panicum texanum* Buckl.)
- Beggarweed (*Meibomia purpurea* Vail.)
- *Crotalaria spectabilis* (Roth), followed by oats
- Brabham or Iron cowpeas, followed by oats

Low index
- Velvet beans, followed by oats
- Crab grass (*Digitaria serotina* Scop.)

Medium index
- Cocklebur (*Xanthium pungens* Wallr.)
- Corn with native vegetation

High index
- Continuous tobacco, followed each year by clean fallow and afterward by oats

Very high index
- Goose grass (*Eleusine indica* Gaertn.)

Texas millet with a very low index and cockleburs with a medium index gave the highest yield and grade of the tobacco crop. Texas millet required heavy cultivation to incorporate it into the soil, and it decomposed slowly; in contrast, cockleburs were harrowed easily, and they decomposed rapidly. The cocklebur rotation has been used extensively by growers.

Nematocidal soil fumigants were studied in twelve experiments con-

ducted over a four-year period, 1946-1949 (13). Ethylene dibromide (EDB), 40 percent by weight at 15 gallons per acre, and dichloropropene-dichloropropane (D-D), at 20 gallons controlled root knot equally well, and gave substantial increases in yield. EDB was preferred to D-D because it gave slightly higher yield, and because it could be applied later in the season without adverse effect.

Other benefits of soil fumigation included an apparently favorable retarding effect of EDB on nitrification (13), and probably some control of certain insects in the soil.

Soil fumigation with EDB was promptly accepted by growers, beginning in 1947 (6). Since then, a large majority of the shade acreage has been fumigated each year. Root-knot control is generally satisfactory, but occasionally poor, due probably to soil improperly prepared, too dry or too cold.

Incidence of root-knot, as measured by the root-knot index, was inversely related to soil pH within the range studied, from pH 5.0 or below to 6.0 or above (11). If this relationship can be verified, it may prove to be of value as a means of root-knot control. Incidence of black shank is unfortunately, on the other hand, directly related to soil pH.

Dixie Shade, which has the root-knot resistant P. I. 706 as a parent, is moderately resistant (9). Rg and Magnolia are susceptible. Breeding for a high level of resistance is in progress, using certain interspecific hybrids (7) and breeding stocks furnished by the United States Department of Agriculture.

Rotation, soil fumigation, and the resistance of Dixie Shade have reduced losses due to root knot to a rather low level for the last several years.

NEMATODE ROOT ROT

Nematode root rot, descriptively called coarse root, which was most recently recognized as a major disease, is apparently increasing in severity during recent years.

Two-year rotations with cockleburs gave a low root-rot index in tobacco in the rotation experiments (8). In recent years, however, cocklebur roots have been found to harbor numerous specimens of Pratylenchus and other parasitic genera, and tobacco following cockleburs has been severely damaged in some instances. It appears probable that certain species or races of these nematodes are capable of developing on both cockleburs and tobacco in a short rotation. Further study is needed to find crops resistant to root-rot nematodes, which could be used to vary the alternate crops.

In fumigation tests, ethylene dibromide controlled nematode root rot better than did dichloropropene-dichloropropane, but neither was considered satisfactory in this respect (13). Experiments are in progress on these and several other nematocidal materials, in an attempt to find something satisfactory.

Incidence of root rot, as measured by the root-disease index, was, to a considerable degree, inversely related to soil pH in certain years (11). The number of parasitic nematodes, primarily *Rotylenchus sp.*, in 1957 was likewise inversely related to soil pH (2). The possible applicability of this relationship to root-rot control is not yet known.

Dixie shade is more susceptible than Rg (9), and Magnolia is less susceptible (10). Breeding for resistance is in progress using breeding stocks from various sources, including root-knot resistant materials which

reportedly carry also root-rot resistance. Some advanced lines are showing indication of considerable resistance or tolerance.

SUMMARY

Progress in research on control of diseases of shade-grown cigar-wrapper tobacco at the North Florida Experiment Station from 1922 through 1959 is reviewed.

Black shank is under rather satisfactory control through the use of black shank resistant varieties, now mostly Dixie Shade, and two-year rotation with other crops. Breeding is continued toward a higher level of resistance, perhaps approaching immunity.

Blue mold is well controlled in plant beds by dusting with zineb, and this treatment is applied also through most of the growing season in the field. The Rg and Dixie Shade varieties are less susceptible than Magnolia or Connecticut varieties. Breeding for resistance is in progress.

Root-knot control by soil fumigation, mostly with ethylene dibromide, is generally effective. Dixie Shade is moderately resistant. Breeding for a high level of resistance is in progress.

Nematode root rot, which has most recently been recognized as a major disease and to which Dixie Shade is highly susceptible, is poorly controlled by soil fumigation with ethylene dibromide. Experiments on other fumigants, and breeding for resistance are in progress.

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Progress Of The Flue-Cured Tobacco (Type 14) Industry In Florida, 1939-1959[1]

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INTRODUCTION

In a review of the literature pertaining to tobacco culture in Florida, Depass'e (11) discussed the culture of tobacco prior to 1900. Depass'e, once Professor of Agriculture and Director of Florida Agricultural Experiment Stations, wrote on tobacco from "seedbed" to "opinions." Moodie (13), with the title of "Special Experimenter with Tobacco" at the Florida Agricultural Experiment Station, wrote "The Culture of Tobacco (Segar) in Florida" (1895). Moodie (14), "Tobacco in Florida," further recorded that George W. Saxon, Tallahassee, was a pioneer in demonstrating Florida's potential in the production of Bright Plug wrapper tobacco. The efforts of Saxon were abandoned because of distance from selling points, as well as the cost of production.

Interest in bright tobacco production was apparently at a very low level from 1900 to 1920 (at least official records are very meager). Long staple cotton was the principal cash crop in Florida and Georgia, and there was little demand or need for expanding production of bright tobacco, due to World War I and the excellent prices obtained for cotton. According to Tilley (17), two factors began to operate simultaneously during the war which increased interest in bright tobacco production: (a) Declining cotton prices and the ravages of the boll weevil; and (b) The increasing and changing demands of tobacco manufacturers, coupled with extremely high prices for tobacco. By 1922, bright or flue-cured tobacco was declared the leading type of the world.

TOBACCO VARIETIES, 1923-1959

The principal varieties of bright tobacco grown between 1923 and 1940 included Warne, Adcock, Hester, Virginia Bright Leaf, White Stem Orinoco, Cash, Gold Dollar, and Bonanza. These were considered narrow-leaf types. Gold Dollar, Virginia Bright Leaf, and Bonanza continued to be popular with farmers even up to the late 1940's.

These varieties were replaced in the 1940's by the wide- to medium-leaf types, such as 402, Golden Cure, Golden Harvest, 401, and Oxford 26. Oxford 26 was developed by personnel from the Oxford Tobacco Station, Oxford, North Carolina, and was the first variety that offered resistance to Granville Wilt. Moodie (13) mentioned that "even though tobacco grows wild in Florida, showing that it is entirely at home in the soil and climate, all florists know that wild plants may be vastly improved by repeated transplanting, cultivation and feeding. Also, as civilization and education advance, the tastes of people are more sensitive and the vagaries of fashion more exacting." Therefore, there has been a gradual transition from the higher nicotine and lower sugars varieties to lower nicotine and

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higher sugars because of market demands. The broad- to medium-broad-leaf varieties were developed to supply the demand for lower nicotine and higher sugar tobaccos.

Black shank, first reported in Florida in 1915, moved into the production area of North Carolina in the early 1940's. Florida growers, however, have not experienced the same trouble with black shank, even though Florida is generally credited with its origin. Thus, the variety picture changed again when DB101 and DB102 were released in the late 1940's by the North Carolina State College and the United States Department of Agriculture. These varieties met with market resistance, even though they provided protection against black shank. Even now, resistance towards new varieties seems to occur.

There have been several varieties of tobacco developed by commercial seed growers as well as by experiment stations since 1939. Until the need to introduce disease-resistant germ plasm became apparent, there was very little concern about varieties. Old standard varieties, however, cannot be grown in some areas because of soil-borne diseases. Thus, the problem of breeding tobacco having the necessary qualities, together with disease resistance, has been of major importance since the early 1940's. Several varieties were developed which produced high yields and had good physical appearance, but were low in taste and aroma. These varieties were widely planted in the disease-infected areas; however, Florida growers did not plant the varieties to any extent. The introduction of these varieties and the development of the filter tip cigarrette came at about the same time. This has led many to believe that these varieties would have been more acceptable had the filter tip cigarette not appeared on the market. Again, vagaries of fashion appear. Florida continues to grow the medium- to broad-leaf varieties such as 402, Hicks, Golden Cure, and Virginia Gold with excellent success. Approximately 85 percent of the acreage grown is of the 402 and Hicks varieties.

1923-1939.—The Tobacco Experiment Station at Quincy, Florida, was begun by enactment of Statute 8424 of the Florida Legislature. Tisdale, employed by the Station on February 15, 1921, conducted disease investigation on cigar-leaf tobacco.

A revival of interest occurred in 1923 when 200 acres were planted in Florida. The first marketing centers for Florida tobacco were established in south Georgia in 1918-19. In 1924, two marketing outlets were established in Florida, at Live Oak and Quincy. The idea implanted by Moodie, who in 1895 described Florida as the "New Eldorado of the United States for production of flue-cured tobacco," really took hold—from 1923 to 1924 acreage increased from 200 to 2,500 acres. Production from 1923 to 1959 is given in Table 1.

A fertilizer and variety experiment, probably the first on flue-cured tobacco, was begun by Tisdale (18) in 1926 on W. L. Taylor's farm. This test included three rates of fertilizer—800, 1,000, and 1,200 pounds per acre of a 3-8-5 analysis. In addition, 12 varieties were also tested. Among these were Adcock, Cash, White Stem Orinoco, Improved White Stem Orinoco, Narrow Leaf Orinoco, Warne, and Improved Warne. Three acres were used in the tests, and all varieties were planted in duplicate rows in each block. A subsequent review of literature failed to mention the results; however, rootknot was reported to be causing severe losses of farmer crops. We can only assume the same happened to Tisdale's tests.

TABLE 1.—PRODUCTION OF FLUE-CURED TOBACCO IN FLORIDA, 1923-1959

Year	Acres Allotted	Acres Harvested	Production (lbs.)	Average Yield (Lbs./A.)	Average Price (cts./lb.)	Value (Dollars)
1923	—0—	200	130,000	650	22.0	28,600
1924	—0—	2,500	1,690,000	676	19.5	329,550
1925	—0—	4,500	3,260,000	722	15.1	492,260
1926	—0—	3,100	2,480,000	800	22.7	562,960
1927	—0—	5,400	4,070,000	754	19.0	773,300
1928	—0—	7,100	4,430,000	624	12.3	544,890
1929	—0—	6,800	5,100,000	750	18.1	923,100
1930	—0—	7,300	5,700,000	781	10.4	600,080
1931	—0—	6,000	4,350,000	725	6.6	287,100
1932	—0—	2,000	1,200,000	600	11.0	132,000
1933	—0—	5,000	3,700,000	740	12.0	444,000
1934	4,300	4,700	3,410,000	725	20.0	682,000
1935	6,800	7,000	6,020,000	860	17.7	1,065,540
1936	8,400	8,000	7,200,000	900	22.0	1,584,000
1937	8,800	16,800	14,110,000	840	21.1	2,977,210
1938	13,500	16,300	15,890,000	975	20.3	3,225,670
1939	14,500	29,500	20,650,000	700	12.3	2,539,950
1940	13,600	12,700	11,750,000	925	17.5	2,056,250
1941	13,669	11,156	8,750,000	784	21.3	1,713,684
1942	15,169	12,649	10,934,130	864	32.3	3,531,723
1943	15,391	13,599	11,698,786	860	40.8	4,773,105
1944	19,911	18,952	16,953,254	895	36.2	6,137,077
1945	21,681	19,094	16,882,724	884	38.8	6,552,437
1946	24,602	20,288	18,891,830	931	47.7	9,011,403
1947	25,786	22,245	23,120,702	1,039	39.0	9,017,073
1948	18,739	16,083	16,302,721	1,014	47.5	7,743,792
1949	19,996	18,730	20,233,098	1,080	37.8	7,648,111
1950	20,199	17,875	18,241,731	1,021	51.8	9,449,217
1951	23,354	22,256	26,971,201	1,212	52.1	14,051,996
1952	23,700	22,504	25,804,706	1,147	51.8	13,366,837
1953	21,999	20,980	22,597,140	1,077	51.4	11,614,930
1954	22,275	21,347	27,596,459	1,293	54.3	14,984,877
1955	21,351	20,894	29,650,170	1,419	46.5	13,799,189
1956	18,822	17,559	21,662,765	1,234	48.6	10,539,000
1957	15,110	11,284	15,361,273	1,361	56.6	8,703,697
1958	15,140	10,965	16,482,441	1,503	57.2	9,424,660
1959	15,142	13,783	19,327,005	1,402	58.8	11,364,279

Data supplied by Economics Department, Florida Agricultural Experiment Station, and the Federal Agricultural Marketing Administration.

The years 1923 to 1932 may be referred to as the "Demonstrator Era" in tobacco production in Florida. Demonstrators were individuals who had experience in tobacco production from other areas, and offered their services for a percentage of the crop (generally 10 percent). The acreage continued to increase until 1930 (Table 1). It is interesting to observe the yearly acreage changes which were apparently influenced by the value of the previous year's tobacco crop. The decline in prices in 1929 also brought about an acreage reduction. There was also a 4,000-acre decline from 1931 to 1932. During 1933 there was a 3,000-acre increase over 1932

Limited marketing supervision was initiated in 1933 (1). The acreage-poundage marketing scheme was the system used during this early period. This practice did not receive acceptance in Florida.

During the "Demonstration Era," J. J. Sechrest, Hamilton County Agent, encouraged the production of bright tobacco in his county, and in the surrounding counties.

The old clay-daubed barns, clay mortar furnaces, and metal flues, together with hand-rived sticks, were standard equipment. Beginning in the early 1930's, oil-burning stoves were used to a limited extent. Frame-type barn construction began to replace the log barns because the grower began to appreciate a need to conserve heat and fuel.

The period 1934 to 1939 was one of gradual expansion in acreage. In 1935 the Tobacco Inspection Act was passed (1). Under this Act, the Secretary of Agriculture could prevent the sale at auction of any tobacco that had not been inspected or certified, provided two-thirds of the farmers approved. This service provided information on leaf quality by grade, and daily market reports were furnished by the Marketing Service which enabled the grower to compare grade with prices. This provided growers with a service that reduced losses to speculators who operated extensively on nearly all markets.

TOBACCO RESEARCH, 1939-1959

The first successfully operated research station for flue-cured tobacco was begun in Chatham, Virginia, in 1906, followed by the establishment of the Oxford, North Carolina Tobacco Station in 1912. The increased interest in problems surrounding the crop, coupled with severe losses sustained with plantbed disease—blue mold—in the 1930's, created an interest for new research with flue-cured tobacco.

The Florida Agricultural Research Institute provided a grant for the initiation of the research in 1939, and the 1939 legislature provided additional funds for research on bright tobacco. The senior author was made responsible for the program beginning in 1938, and continuing to the present time.

As early as 1895, Moodie (13) had mentioned the peculiar soil and climate of Florida, together with the need for information in handling a special crop like tobacco. Moodie, in writing about fertilizer, states that "it is not the aim of the expert grower to produce simply a good crop of tobacco, but more particularly a crop of good tobacco; and while we must not undervalue the importance of quantity, quality is more important. A small yield per acre, however, is very apt to be of poor quality. Therefore, in order to insure both quality and quantity of tobacco, it is necessary (with very few exceptions on some of the richest virgin soils) to apply liberally a well-balanced fertilizer. This [fertilizer] should be readily soluble so that the plant may assimilate it very quickly as the tobacco plant is short lived, sometimes maturing in 40 to 50 days [after transplanting] when all conditions are favorable."

Moodie's quality standards were "The goods must be sweet, aromatic, pretty as a polka-dot, smooth as silk, glossy as satin and as thin and elastic as a bat's wing. And having all of these qualities in the highest degree, it will be utterly worthless unless it burns well." Moodie further states "the quality of perfect combustion is most essential and while all are important

and must be considered in the compounding of this complete, well balanced highly soluble, nutritiously prepared food or fertilizer."

Thus, we not only have the foundation, but the need for a balanced fertilizer, vividly depicted.

Early experimental work in other states established the role of commercial or chemical fertilizers in increasing yields. With this increase in yields, bright tobacco challenged burley as the leading type.

1939-1944.—As Florida soils are sandy and low in organic matter, the first problem was to establish fertilizer levels (4). The early fertilizer program used by farmers had included a bag of lime and a bag of fertilizer. The fertilizer ratios included 2-8-3 and 3-8-3. By 1939, over 90 percent of the tonnage used for bright tobacco was of a 3-8-5 analysis. The inclusion of lime in the fertilizer program had declined during the early 1930's because of the report of Darkis *et al.* (10) dealing with the effect of lime on quality. This report is still worthy of note.

During these years, Florida growers generally had an adequate acreage of land on which to grow tobacco without having to consider rotations. The wealth of virgin land proved to be the "Eldorado" mentioned by Moodie (11).

The early fertilizer trials (4) indicated a need for additional potash, and that nitrogen sources influenced leaf quality. Leaf roll in Florida was first demonstrated on tobacco in the 1939 fertilizer trials at Gainesville. In the source-of-nitrogen tests it was shown (7) that nitrate nitrogen would eliminate the roll. Because of the declining acreages under the Federal Planting Quota systems during 1933-1939, farmers were very much interested in plant spacing and fertilizer rates to increase yields and at the same time maintain a good quality leaf.

Just prior to and during World War II, there was a tremendous increase in tractor farming. The tractor reduced the number of hours of labor in land preparation and cultivation. It was also the beginning of the end of the "golden age" of mule cultivation of tobacco. Tobacco provided capital for land and machinery expansion during this era. During this early pre-and post-war period, several movements were intermingled. The increased use of tractors for farming led to the gradual increase in size of farms, which has continued until the present time (Table 2). The tractor served as a laborsaver, and the "Cracker farm" idea of farming was discontinued. Essentially, this was a rotation of fallow or idle land for 1 to 3 years in cropping sequences. This was sometimes called "rested" land.

TABLE 2.—AVERAGE SIZE OF FARMS—CENSUS YEARS, SELECTED FLORIDA TOBACCO COUNTIES

County	Farm Acreage			
	1940	1945	1950	1954
Alachua	123	181	199	246
Columbia	127	148	269	266
Hamilton	148	172	201	237
Lafayette	138	153	205	219
Madison	134	155	182	215
Suwannee	136	149	159	185

Source: U. S. Census Reports for Florida. Courtesy E. W. Cake, Extension Economist and R. E. L. Green, Economist, Florida Agricultural Experiment Station.

Also, the competition for virgin land began to appear at the same time as a result of the coming of the pulpwood industries.

As the Cracker farm idea of farming was discarded and the availability of virgin lands gradually decreased, there was added interest in tobacco plant production. Thus, the "Permanent Seed Bed" (8 and 7) entered the picture. The overall difficulties of having tobacco plant available at the right time contributed to the lack of increase in yield from 1930 to 1939.

Another project of importance was begun by the Station investigators during this period—the search for nematode resistance in tobacco (9). This has been a very difficult problem; however, some progress has been made. From 1939 to 1944 may be called the "Orientation Years."

1944-1949.—A new method of producing plants was started during World War II, and progressed rapidly immediately thereafter. Large field areas, as much as 100 acres, were seeded to tobacco in several south Florida counties. This practice came about because many growers in the Florida-Georgia production area figured that they could purchase plants cheaper than they could grow them. Following a few successful field beds, and because there was no blue mold in south Florida, this method of plant production grew very rapidly. Since the early 1950's, growers in south Florida have experienced blue mold and virus infection of plants. Three viruses have been isolated from south Florida plants, namely tobacco etch virus, potato-Y virus, and common mosaic. Relatively high infection of some Florida plants led to a quarantine by the Georgia State Plant Board for 1960. The quarantine extends south, east, and west of Orange County.

From 1944 to 1949, the average yields began to increase slightly. Contributing factors included increased rates of potash and more plants and fertilizer per acre. During this period, numerous chemical materials were being developed by chemical companies, notably the carbamate organic fungicides, chlorinated hydrocarbons and phosphatic insecticides, and the fumigants EDB and D-D. Many have proven valuable.

Two areas of investigation were begun during this period. The evaluation of fumigants (6) and the first large-scale field irrigation experiments in the United States for flue-cured tobacco were started in 1948-49 (3). The role of soil fumigants cannot be underestimated in the development of the irrigation research. The high cost of production of flue-cured tobacco, coupled with inadequate control of nematodes, kept interest in irrigation to a minimum for many years. Soil fumigants provided for economic control of nematodes, which in turn provided better risk protection for the growers. Yield and quality of tobacco leaf were greatly improved with irrigation and soil fumigation. Yield increases ranged from 20 to 35 percent, and the price per pound increased from 2 to 7 cents. Thus, soil fumigants and irrigation proved to be excellent teammates. Research during 1944-1949 included work with fungicides, insecticides, fumigation, nitrogen sources, and irrigation.

The principal marketing activity during 1945-1949 was the introduction of the support price program, based upon grade or leaf quality. This program, initiated in 1946, and operated under the Flue-Cured Tobacco Cooperative Stabilization Corporation, with headquarters in Raleigh, North Carolina, stimulates growers to increase yields and improve quality.

1950-1954.—Research during this period included a continuation of the work begun in the late 1940's. The Suwannee Valley Experiment

Station at Live Oak, Florida, was established November 1, 1950, with G. E. Ritchey in charge. Under the direction of H. W. Lundy, tobacco and crop and soil problems are under investigation at the present time.

A review of the state average yield data shows a fairly sharp increase in yields beginning in 1951. This was the first year that soil fumigation was used commercially. In addition, the question was raised in regard to the interaction of present fertilizer recommendations with irrigation. Thus, the problems of "when" and "how much" irrigation water and fertilizer, as well as plant and row spacing, were investigated (5 and 15). There was little need for change in the fertilization program; however, more dry weight leaf was produced per pound of fertilizer with irrigation. The approximate ratios of yield to pounds of fertilizer for cured leaf from the period 1923 until this time are shown on the following page. These ratio increases may be explained by more and better seedlings for transplanting, resulting in uniform stands, irrigation, control of nematodes, and more judicious use of fertilizers.

RATIO OF CURED LEAF YIELD TO POUND OF FERTILIZER

Period	App. Yields	Lbs. Fertilizer
1923-38	.70	1.00
1939-43	.90 to 1.00	1.00
1944-49	1.00 to 1.20	1.00
1950-54	1.20 to 1.40	1.00
1955-59	140 plus	1.00

During the early 1950's many farmers began to realize the value of the more poorly drained soils for tobacco because of their water-holding capacity during periods of drought. The use of these soils was not always favorable because of the greater soil acidity. Where the pH was extremely low, applications of dolomitic lime were recommended (1,000 to 2,000 pounds per acre).

Previous research had demonstrated the effect of nitrate nitrogen in reducing leaf roll; however, the average nitrate level in most tobacco fertilizers was still lower than required for correctional purposes on these strongly acid soils. The industry has cooperated in providing a more favorable ratio of nitrate nitrogen in fertilizer for tobacco. Inorganic sources of nitrogen have not been completely accepted by all farmers.

The following recommendations were made by the Agronomy Fertilizer Committee of the 1959 Tobacco Workers Conference (12) with regard to nitrogen fertilization. The amount and form of organic matter, texture of the surface soil, and depth to subsoil (clay) are important characteristics influencing the quantity of nitrogen required for sandy soils of average fertility. The following guide indicates quantities of nitrogen which have been found to be generally adequate:

Depth to Clay	Nitrogen Suggested (Lbs./Acre)
0-12	30-40
12-18	40-50
18-24	50-60
24 plus	60 plus

On heavy-textured, very fertile soils, 20 to 30 pounds of nitrogen will generally be sufficient. On sandy soils that are more than 24 inches to clay, 60 to 70 pounds of nitrogen may be necessary. Preplant and sidedressing fertilizers should contain at least 30 percent of the total nitrogen in nitrate form.

Split applications of fertilizer were found to be advantageous with irrigation from 1949-51 (3), and the same was true for the 1952-55 tests (5). When irrigation is used, therefore, a split application of fertilizer is highly desirable. Fumigated soil, fertilized at the rate of 1,500 pounds of 4-8-12 with 2 percent magnesium and not more than 2 percent chlorine and with 7,500 to 10,000 plants per acre, seems to give the best production with irrigation.

The effect of maleic hydrazide on sucker control was tested during the 1950-1955 period, and recommendations were made (2).

A schedule for applying irrigation water was also developed during the 1953-55 period (15).

The high point of the 1950-1954 era was the increased use of irrigation in combination with other recommended practices. This acceptance certainly contributed to the continued increase in yields, which averaged 1,419 pounds in 1955. Yields per acre were doubled from 1939 to 1955 (Table 1).

1955-1959.—Research investigations for this period have given more consideration to varieties, particularly since some high-yielding varieties were not accepted by the industry. The first scientific approach to curing tobacco in Florida was begun by the Florida Experiment Station in 1956 (16). Curing research has proven very informative, and is being continued. Correlation of fertilization (particularly nitrogen rates) and maturity at harvest are being tested. Five yellowing temperatures are also being used in the curing procedure. Maturity and yellowing of the leaf in curing is of prime importance in developing the desired "face" of the leaf. In addition, tests involving varieties, nitrogen rates, and time of irrigation are being tested. Bulk curing, which has great potentialities as a laborsaver, has been introduced into the research program.

In 1956, the junior author assumed the responsibility of Bright Tobacco Extension Specialist. This phase of the program had previously been handled jointly by Extension and Station personnel. The Extension district agent handled the program until 1947, at which time an agronomist was appointed who assumed Tobacco Extension Specialist work along with his other duties.

Plantbed research, on types of bed covers, planting dates, and varieties, is now under way. Results of these tests, however, have not yet been made available.

During the early 1940's and 1950's, many farmers became interested in planting grasses for forage and seed. Pensacola bahiagrass was planted extensively in the tobacco-producing area; and, beginning around 1955, many growers were plowing under their grass pastures for tobacco and other crops. Tobacco was one crop that grew exceptionally well on the newly-turned grass sods.

The need for nitrogen is apparently greater on grass sods than on cultivated fields, due to the rapid utilization of nitrogen by soil organisms. In the absence of adequate nitrogen fertilization, tobacco will turn yellow much faster on grass sod soils than on cultivated fields.

TABLE 3.—ACRES OF TOBACCO BY AVERAGE ALLOTMENT, PERCENT ALLOTMENT, PERCENT OF FARMS AND NUMBER OF ALLOTMENTS FOR 1957

Acres	Average Allotment	Percent Allotment	Percent Farms	Number of Allotments
0.01- 0.59	0.28	1.3	9.8	671
.60- 1.09	.83	4.8	12.8	872
1.10- 1.59	1.28	15.5	26.8	1,830
1.60- 2.09	1.85	12.9	15.5	1,056
2.10- 2.59	2.34	10.7	10.7	689
2.60- 3.09	2.81	7.9	6.3	426
3.10- 3.59	3.32	7.9	5.3	363
3.60- 4.09	3.85	4.5	2.6	175
4.10- 5.09	4.53	8.1	4.0	271
5.10- 7.59	6.06	10.2	3.7	254
7.60- 10.09	8.63	6.4	1.7	113
10.10- 15.09	12.24	5.6	1.0	69
15.10- 20.09	16.74	1.8	0.2	16
20.10- 30.09	23.83	1.6	0.2	10
30.10- 40.09	---	---	---	---
40.10- 50.09	41.53	0.3	Less 0.1	1
50.10-100.00	70.95	0.5	Less 0.1	1
TOTAL	2.22	100.00	100.00	6,817

Courtesy Florida Production and Marketing Administration, Gainesville, Florida.

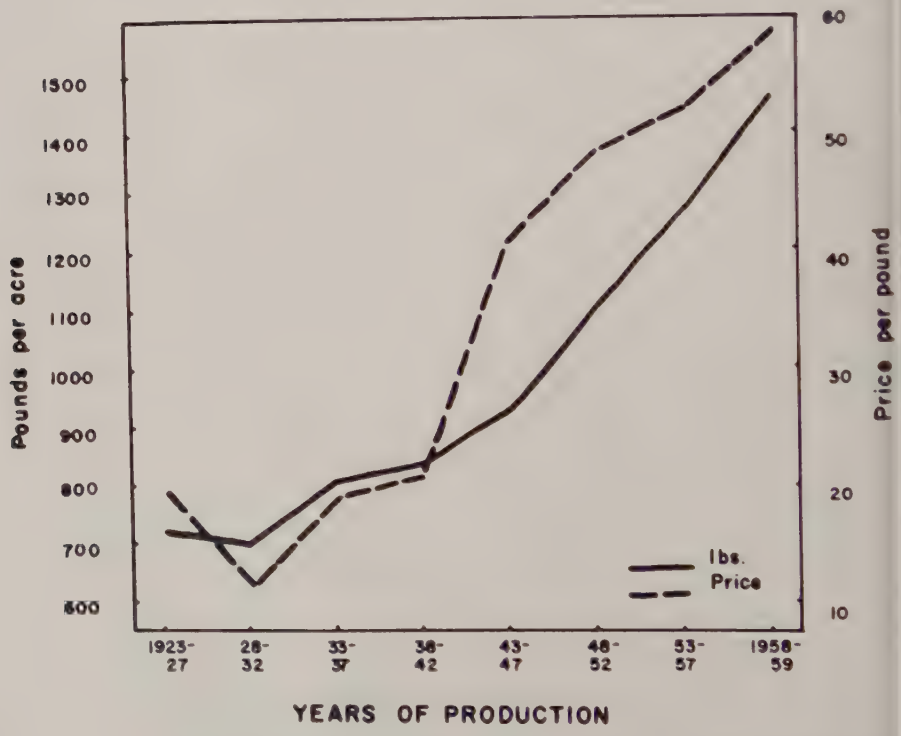

Figure 1.—Yield and price trends for flue-cured tobacco in Florida, 1923-1959.

TABLE 4.—Tobacco Farm Allotments, Average Acreage, Allotment Acreage, Total Production and Yield Per Acre by Counties—1958-59

Counties	Allotments		per Farm		Acreage		Lbs. Total Production		Average Yield per Acre (Lbs.)	
	1958	1959	1958	1959	1958	1959	1958	1959	1958	1959
Alachua	671	539	2.87	3.12	1,922.88	1,921.83	1,901,813	2,342,293	1,498	1,392
Baker	181	150	1.45	1.52	261.56	262.62	187,260	213,058	1,455	936
Bradford	104	61	2.38	2.90	247.89	252.24	77,624	176,514	1,300	999
Calhoun	2	1	1.30	1.89	2.60	2.60	0	1,408	0	745
Columbia	874	800	1.88	1.90	1,644.15	1,646.43	1,803,419	1,988,003	1,533	1,309
Dixie	73	62	1.55	1.67	113.38	114.49	103,535	152,884	1,460	1,476
Duval	2	1	.95	1.18	1.90	1.90	658	472	548	400
Gadsden	170	124	1.28	1.28	217.62	218.44	143,074	195,360	1,218	1,227
Gilchrist	269	214	1.48	1.55	396.78	396.77	354,496	396,659	1,215	1,192
Hamilton	501	488	3.85	3.87	1,928.90	1,930.83	2,972,835	3,075,025	1,742	1,628
Hillsborough	2	0	.55	0	1.10	1.10	0	0	0	0
Holmes	37	30	1.13	1.31	41.83	42.87	48,240	29,878	1,460	760
Jackson	133	103	1.27	1.36	169.13	169.30	94,078	158,122	1,100	1,128
Jefferson	250	197	1.38	1.42	345.09	345.37	221,810	388,540	1,331	1,387
Lafayette	431	405	2.59	2.66	1,115.67	1,116.79	1,466,798	1,560,863	1,606	1,447
Leon	31	16	1.31	1.85	40.59	40.63	28,266	36,112	1,354	1,221
Levy	114	78	1.34	1.47	152.57	153.67	69,450	110,512	978	961
Liberty	2	1	.61	.80	1.22	1.22	0	916	0	1,145
Madison	1,055	939	1.86	1.94	1,963.64	1,967.63	1,858,474	2,650,774	1,409	1,456
Marion	12	1	1.70	3.90	20.40	20.42	3,426	4,632	867	1,188
Nassau	43	33	1.50	1.58	64.67	64.73	67,342	52,366	1,748	1,004
Orange	4	0	.52	0	2.10	2.10	0	0	0	0
Polk	1	0	.37	0	.37	.37	0	0	0	0
Sumter	38	33	1.07	.86	40.81	41.14	24,248	24,534	1,062	866
Suwannee	1,556	1,436	2.36	2.39	3,678.68	3,684.71	4,374,271	4,960,345	1,445	1,446
Taylor	202	164	1.52	1.70	307.81	308.12	235,234	415,759	1,362	1,490
Union	206	184	2.21	2.13	454.38	454.83	446,050	392,066	1,664	1,002
Volusia	2	0	.67	0	1.34	1.34	0	0	0	0
Washington	1	0	1.34	0	1.34	1.34	0	0	0	0
State Total	6,967	6,060	2.17	2.27	15,140.40	15,168.83	16,482,441	19,327,005	1,503	1,402

Courtesy Florida Agricultural and Marketing Administration, Gainesville, Florida.

The principal marketing activity of this period was the "Soil Bank" program. Over 3,000 acres were placed in the program during 1957-58. The "Variety Discount" program was another marketing factor during this period. Growers who planted the discounted varieties were penalized at the market.

From the research standpoint, curing procedures have highlighted the period. From the grower's standpoint, interest has centered around changes in fertilizer ratios and sources (particularly nitrogen), irrigation, fumigation, sucker control, and recommended varieties. Yields have continued to increase, but indications are that the peak has not been reached. Many counties are now producing yields well above the state average. The average yield per acre in Hamilton County in 1958 was 1,742 pounds and sold for $59.30 per 100 pounds.

All the advances cannot be attributed to any one thing; however, it is felt that research and extension have played an important part in the progress that growers have made.

TABLE 5.—FLORIDA FLUE-CURED TOBACCO MARKETS

Market Centers	Date	Active
Live Oak	1924	Continuous
Quincy	1924	No
Madison[1]	1928-1955	Alternate
Lake City	1938	Continuous
Jasper	1947	Continuous
High Springs	1953	Continuous

[1]Market has not operated continuously.

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Note: Figure 1 illustrates the yield and price trends for flue-cured tobacco from 1929 to 1959; Tables 3 and 4 present information by counties on tobacco acreages, yields, and values for 1957 through 1959; and Table 5 lists Florida Flue-Cured Tobacco Markets.

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A Brief Review Of Sugarcane Research In Florida, 1939-1959[1]

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The earliest sugarcane research in Florida consisted mainly of testing varieties introduced from the tropics. While a few of them produced fairly well, their sugar production was generally unsatisfactory. Although work was carried out on fertilization, pathology, and entomology, most of the work was concentrated on the breeding and production of seedlings. South Florida is the only place in the United States where sugarcane tassels, or arrows, every year under natural conditions. In north Florida and Louisiana, tassel initials have been observed but not brought to maturity except in the greenhouse or during rarely occurring years with a mild winter. November to February is the normal time for blooming in the northern hemisphere. The outstandingly successful work of the Dutch in Java along with the above mentioned facts spurred investigators to initiate in South Florida sugarcane breeding research which proved to be exceedingly productive.

Since 1950, the Agricultural Research Service of the United States Department of Agriculture (USDA) has had stationed at the Everglades Experiment Station an entomologist who has been working primarily on sugarcane insects. A full-time plant pathologist has been stationed at Canal Point, Florida since December 1954 whose interests have been primarily concerned with the World Collection of sugarcane at Canal Point, the USDA quarantine program, and the breeding program. The investigations of weed control for sugarcane are excluded from this paper as they will be presented in a separate article.

SUGARCANE BREEDING

The appearance of mosaic in the United States over forty years ago with its consequent reduction of yields of cane, sugar, syrup resulted in the initiation of research in methods of combatting that menace. At

[1]Florida Agricultural Experiment Station Journal Series No. 1019.

[2]Plant Physiologist, Emeritus, Everglades Experiment Station; Agronomist, USDA; Assistant Agronomist, Everglades Experiment Station; Plant Pathologist, USDA; and Entomologist, USDA, respectively.

[3]Research work on sugarcane is carried on cooperatively with the University of Florida Agricultural Experiment Station and USDA.

first this entailed introduction of varieties from Java and India, some which were resistant to mosaic. In the beginning most of the work was carried on at Canal Point. Crosses and first selections were made there and, after trial, were sent to the USDA stations at Houma, Louisiana and Cairo, Georgia. In 1929 the Southern Sugar Company of Clewiston Florida initiated cane breeding work on the production of new varieties for its own plantation requirements. In 1930 the Everglades Experiment Station started agronomic and breeding work with sugar cane.

This work was carried cooperatively with the United States Sugar Corporation (USSC) newly formed from the relict Southern Sugar Company. The nature of the cooperation was the production and testing of the "F series" seedlings on the USSC plantations and at the Everglades Experiment Station. Beginning in 1935 the Everglades Experiment Station and the USSC carried on independent cane breeding operations. There was, however, cooperation in exchange of parental material and land used for growing male-fertile breeding clones on one of the USSC plantations. Until 1949 the cooperation with the USDA consisted principally of exchange of breeding material. Beginning in 1949, the most promising "F series" selections were sent to the USDA Sugar Plant Field Station at Houma, Louisiana, for artificial infection with a mixture of mosaic strains A, B, and D. Since 1952 the Everglades Experiment Station has been artificially inoculating its young seedlings in flats with a mixture of strains A, B, and D, in cooperation with the Canal Point Station. In addition to those seedlings produced by the Everglades Experiment Station some seedlings produced at Canal Point have also been planted at the Everglades Experiment Station. First selections were then planted in line tests at Okeelanta and Fellsmere as well as at the Everglades Experiment Station. In 1957 and 1958 seedlings also have been planted at Fellsmere, obtained from both the Everglades Experiment Station and the Canal Point Station. In the spring of 1959, a total of 88,341 seedlings, from crosses made at Canal Point (4), were space planted singly and in bunches of seven to fields of the Everglades Experiment Station, Okeelanta, Florida and the Fellsmere Division of the Okeelanta Sugar Refinery, Inc.

Until about 1950 most of the cane produced on about 30,000 acres in the Florida Everglades has been from the varieties F. 31-436 and F. 31-962. Another variety released in 1946, F. 40-90, was extended to about 1500 acres. Since about 1952, Cl. 41-223, bred and developed by USSC, has been rapidly extended and is gradually replacing F. 31-436. At present Cl. 41-223 occupies over 80 percent of the total acreage of sugarcane in the Everglades, this because Cl. 41-223 has been found to be more cold resistant and does not suffer from red rot and mosaic. F. 40-96 was an earlier and sweeter cane than F. 31-962 but suffered greatly from ratoon stunting disease. Cl. 47-83, an early sweet cane, has replaced F. 31-962 during the last three years. At Fellsmere C.P. 50-28, released in 1957, has been extended. It is an early, sweet cane supplementing C.P. 34-79 and F. 36-819 on the more acid mucks found in that area.

During the period 1939-1959, 15 varieties of sugarcane bred at the USDA Sugarcane Field Station, Canal Point, were released for commercial sugar and syrup production in the Gulf States. All of these varieties are complex tri-species hybrids involving germ plasm from the thick-stemmed *Saccharum officinarum* L. (noble) forms, the slender-stemmed *S. barberi* (Chunnee) varieties of northern India, and the widely distributed forms of the thin barrelled wild species, *S. Spontaneum* (2). The three most important

C.P. varieties developed during this period were C.P. 34-120, C.P. 36-105, and C.P. 44-101, and all were released for sugar production in Louisiana. At present C.P. 44-101 is the dominant variety in Louisiana, occupying about 48 percent of the sugarcane acreage. C.P. 52-68, released to growers in 1958 is being rapidly extended in Louisiana, and shows promise for adaptability in Florida. C.P. 34-79, bred in 1934 and released to growers of southern Florida in 1945 is now the dominant variety at the Fellsmere Division of the Okeelanta Sugar Refinery Inc.

A large-scale expansion of the sugarcane breeding program at Canal Point was inaugurated in 1948 to speed up the development of new cane varieties adaptable to culture in Louisiana, Florida, and the syrup-producing areas of the southeastern United States. The Louisiana Agricultural Experiment Station, through cooperative arrangement with the American Sugar Cane League and the USDA, agreed to enter into the growing, selection, and testing of original seedlings produced from crosses made at the USDA Sugarcane Field Station at Canal Point. A regular exchange of original sugarcane selections is made each year between the state and federal stations in Louisiana, Mississippi, Georgia, and Florida; selections made in one particular area often prove of significant value in another area far removed. A world collection of breeding material, comprising approximately 2000 varieties of sugarcane and related grasses, is maintained at Canal Point.

With the expansion of the sugarcane breeding program cane inherent problems which were met and overcome as even newer problems were posed. Up-to-date breeding techniques were developed and advanced (3) in order to increase production of viable true seed. Improved methods for rooting flowering stalks of sugarcane on a mass basis have been perfected since 1948 in the conversion from a system of hazardous outdoor crossing to a system of controlled crossing under favorable microclimatic conditions insuring protection from destructive winds, rains, and low temperatures. Since 1948, improved techniques in the crossing program at the Canal Point Station have resulted in better parental combinations and seed production beyond the expectation of two decades ago, when a "good" crossing year resulted in the production of a total of 5000-10,000 viable true seed. In 1958, an estimated 2,076,614 viable true seed were produced at Canal Point (4) and 529,082 seedlings were set in the fields of the cooperating agencies in Florida, Louisiana, Mississippi, and Georgia.

Concomitant with increased seed production in the last 10 years, new and improved methods have evolved for handling large numbers of seedlings on an efficient basis. Personnel and greenhouse space has necessarily been greatly increased. Procedures in potting seedlings, disease inoculations, and field transplantings of young seedlings have been modified greatly or changed completely. Agronomic testing and increase of promising new varieties have been intensified. Hundreds of varieties obtained from crosses made during the early years of the expansion (1948-53) are finally being appraised and one variety, C.P. 52-68, from a 1948 cross, was released in 1958 for commercial sugar production. Nature has alloted a minimum of 8-10 years to breed, select, and develop a new variety of sugarcane.

CANE SOILS AND FERTILIZERS

Sugarcane for sugar production in Florida is grown in the Everglades on muck soils varying in depth from three to eight feet.

Three distinct zones of organic soils are employed at present for growing sugarcane and other crops. Bordering Lake Okeechobee to the southeast and extending back in a strip from one to four miles wide were original forests of custard apple. Further back, south of the custard apple land was the zone of willow-and-elder. Sawgrass was the principal native vegetation in the remaining part of the Everglades region suitable for row crops. The soils of these three areas are classified generally as Okeechobee muck, Okeelanta peaty muck, and Everglades peat, respectively.

Muck and peat soils are brown to black in color and consist of 65 to 90 percent organic matter. Muck soils in the Everglades area used for the growing of sugarcane are underlaid by limestone or an intermediate layer of sand and marl.

The total annual rainfall in the Everglades is over 54 inches per year (5) of which more than 38 inches falls between June and October. Evaporation (5) from bare soil is approximately 40 inches per year and from a soil covered with several inches of cane trash only 11.6 inches. These amounts are, respectively, 62 and 18 percent of the evaporation from the open pan and 70 and 20 percent of the normal rainfall.

Ten years results from tanks planted with sugarcane averaged 49 inches evaporation per year, which was 76 percent of the evaporation from the open pan and 86 percent of the mean rainfall during the period. The average depth of the water table was about 1.5 feet, which approximates field conditions.

During the months when the precipitation is higher than the evaporation, the excess of water is drained by pumps. During the dryer periods, the water table is maintained at around 1.5 feet from the surface by admitting water from canals flowing from Lake Okeechobee. For drainage and irrigation, an extensive system of canals is maintained. To secure a speedy removal of excess water most fields are mole drained.

Peat and muck soils of the Everglades are deficient in many minor elements needed for the production of sugarcane. Soils not treated with copper failed to grow a cane crop while soils treated with 75 pounds of copper sulphate per acre produced a yield of 50 tons millable cane per acre (6). Cane stools growing in copper-treated soils have failed to produce a root system when layered in untreated soils. Cane growth was retarded for the first 5 to 6 weeks on some copper-treated soils but recovered and grew normally thereafter. The copper deficiency symptoms in the early days were often mistaken for mosaic disease (6). If zinc were not supplied to the soil, cane had a normal start but became stunted after 5 weeks growth. However, with a sufficient application of copper and zinc, cane plants grew normally throughout the season (6). Since a normal cane crop is dependent upon adequate copper and zinc applications, the acreage under cultivation in the Glades has been fertilized regularly with copper and zinc. This practice has been so adapted that it is difficult to find any sugarcane acreage now deficient in these elements.

Rates of 10,000 pounds per acre of zinc and copper sulphate have been applied experimentally to the soil without ill effects to the cane plants (6). This is due to the high base exchange capacity of these organic soils. The actual availability of these elements for the use of the cane plant under the existing soil conditions is a factor to be considered when these large amounts were applied.

It has been found (7) that sugarcane does not respond to applications of nitrogen in the Everglades. A response to a potassium application was

obtained in most fields. The results indicate that no difference was found in tonnage or sucrose yield between muriate or sulphate of potash (8). In plant and stubble cane 200 pounds per acre per year of either form of potash seems to be the most economical application rate (9).

Analyses of samples from plots showing potash deficiency revealed a condition of low sucrose and of increased amounts of invert sugars and hemicelluloses (10).

The response to phosphorus seems to be more complex. Until 1947, only an unfavorable response to applications of soluble phosphate to the soil was obtained with a pronounced increase of the phosphorus content as well as the total acidity of the cane juice (8), (10), (11), (12). At that time with a high P_2O_5 content in the original soil, rock phosphate did not increase the P_2O_5 content in the juice. However, an application of sulphur to the soil did increase the phosphate content of the juice and a lime application depressed it (13). The residual effect was much greater when superphosphate was applied than when basic slag or rock phosphate was used (11).

Sugarcane planted on plots where soluble phosphate had been applied showed a retarding of growth which was not observed on plots that received no soluble phosphate or rock phosphate (10).

As time progressed and the high phosphorus content of the original soil decreased by cropping or fixation, the situation was reversed. In 1947 an application of superphosphate yielded a significant increase of 0.89-1.22 tons of 96° sugar per acre over the controls in plant fields, while the residual effects of the phosphate application was even greater in the stubble crops (14). A standard application is now 80 pounds per acre of triple superphosphate, 47 percent P_2O_5, on phosphate-deficient fields.

No response was found to magnesium and calcium, likely because of the underlying limestone.

PHYTOPATHOLOGY

During the past 20 years diseases have continued to stimulate the development and propagation of interspecific hybrids of sugarcane varieties which are resistant to the devastating effects of parasitic fungi, bacteria, viruses, and possibly nematodes.

Mosaic of sugarcane, caused by a virus, is one of the classic diseases in the history of Phytopathology (15). This malady nearly throttled the production of sugarcane in Louisiana in the 1920's. As a result of strenuous research and development since that time, great strides were made in the production of resistant varieties which stabilized the sugarcane industry. Within the past few years, however, the appearance of a new strain of the virus and the release of susceptible varieties have created a growing concern that mosaic again poses a threat to the production of sugarcane in Louisiana (16), and in Florida as well. Since mosaic cannot be controlled by any known method of treatment, renewed efforts are being made toward the further development of resistant varieties.

A new virus disease of sugarcane, ratoon stunting disease (RSD), was discovered in Australia in the 1944-1945 crop. It has since been identified in major cane growing areas throughout the world, including Florida. RSD has caused much interest in the possibility that it is an important factor in the failure or "running out" of varieties (17). This has been confirmed

by extensive studies which have revealed staggering losses in yield of cane of certain varieties. These losses can be directly attributed to RSD. Hot-water or hot-air treatment of sugarcane seed pieces is recommended for the control of this disease. In fact, several varieties of commercial importance have been rejuvenated by the heat treatment of sugarcane. Because RSD is a relative newcomer, much basic work remains to be done in order to better understand the disease.

Red rot of sugarcane in Florida has been demonstrated by Bourne (18) to be associated with two fungi, *Colletotrichum falcatum* Went and *Fusarium moniliforme* Sheldon. This disease complex is of major importance in the Florida Everglades. Heavy losses are often sustained in standing cane of susceptible varieties. Various treatments do not give practical control of this disease. For this reason, red rot also is a prominent factor in determining the selection and subsequent release of new varieties of sugarcane.

Other diseases in Florida usually assume lesser positions of importance in the production of sugarcane. Some of these are: brown stripe, *Helminthosporium stenospilum* Drechs.; eye spot, *H. sacchari* (Breda de Haan); Butl. brown spot, *Cercospora longipes* Butler; pokkah boeng, *Fusarium moniliforme* Sheldon var. *subglutinans* Wr. and Reinking; red stripe, *Xanthomonas rubrilineans* Starr and Burkh. On occasion each of these diseases has caused concern. Consequently, resistance to them is carefully considered in the breeding and selection programs.

Although the role of nematodes in the sugarcane disease picture in Florida is not clear at this writing, there has been some evidence of nematode damage to sugarcane. Data concerning this problem are presently being accumulated.

ENTOMOLOGY

In southern Florida the foliage of sugarcane is burned in the field before the crop is cut. It has been observed that most sugarcane borers (*Diatraea saccharalis* (F.)) present in the stalks are killed by the heat produced. A thermometer placed inside the cane stalks and tops showed maximum temperatures of 125° to 190° F. during the burning. Living fourth and fifth instar larvae immersed in fresh water at various temperatures showed that the non-hibernating borers will not survive temperatures of 125° F. for 2 minutes, 130° for 30 seconds, 135° for 15 seconds, 140° for 5 seconds, or 155° or 190° for 1 second (19).

Most borers removed from stalks following burning were dead or died a few days later. It is believed this practice of burning cane where tonnages are 40 or more per acre, aids greatly in controlling the sugarcane borer. Before the practice of preharvest burning was begun borer populations were greater. Fields that are not burned such as chewing cane and experimental breeding plots, usually carry heavier borer populations than burned fields.

Endrin is being used successfully to control the borer in Louisiana but borer populations in most cases are too light to justify the use of insecticides in southern Florida.

The wireworm *Melanotus communis* (Gyll.) can be kept under control by spraying the seed pieces and the open furrow at the time of planting with heptachlor, chlordane, or aldrin. Significant increases in yields fol-

lowed these treatments in randomized block tests. Many other soil insects, such as the white grub *Cyclocephala borealis* Arrow, were killed by these treatments. Losses caused by wireworms were much greater before the use of chlorinated hydrocarbons.

Demeton, malathion or parathion applied as a spray at the rate of one-half pint in 40 gallons of water per acre gives good control of the yellow sugarcane aphid (*Sipha flava* (Forbes)). In two fields heavily infested with yellow sugarcane aphids, 100 percent control was obtained with demeton. However, these insecticides will kill predators, which if left alone, usually will control the aphids before too much damage is done. Ladybugs (Coccinellidae) are especially beneficial.

Recent increases in aphid population are believed to be related to the expansion of cattle pastures especially of Pangolagrass which is very susceptible to the yellow sugarcane aphid.

Fungus diseases play an important part in aphid control. Spores of the fungus *Acrostalagmus aphidum* Oudemans, obtained from Puerto Rico through the efforts of the United States Sugar Corporation, have been scattered over cane fields and appear to be effective, particularly during rainy weather.

Endrin is effective against the lesser cornstalk borer (*Elasmopalpus lignosellus* (Zell.)). On muck soil 300 to 500 gallons of water per acre is necessary to penetrate the top of the soil where larvae are hiding. In 1956 endrin-sprayed plots had about 50 percent more shoots and the plants were about a foot taller than those in untreated plots two months after application. At harvest time, there were more millable canes in the endrin treated plots, however, the canes in the check plots were larger in diameter and there were no significant differences in yields.

Some sugarcane varieties are more susceptible to damage by the lesser cornstalk borer than others. In a trial of 25 varieties, Cl. 41-223, the variety most widely grown in southern Florida, showed the highest degree of resistance to the lesser cornstalk borer.

During the past five years, many thousand parasites and predators have been released in southern Florida to combat insect pests. The most successful of these was the release made of *Anagyrus antoninae* Timberlake (20).

Since Rhodesgrass scale could not be economically controlled in pastures with insecticides, parasites were introduced in 1954. In July, 800 *Anagyrus* parasites were released near Clewiston for control of the scale. The wasps, originally from Hawaii, were reared by and received from Herbert A. Dean of the Texas Agricultural Experiment Station and collaborator with the USDA Entomology Research Division, Weslaco, Texas. The original release was made on Paragrass heavily infested with this scale. Previous collections had shown that the parasite was not in the area. No further importation of the insect was made and now the parasite has spread over a hundred-square-mile area from the original release. Recoveries have been made twenty-five miles from the release point. Scale populations have greatly decreased in the areas of the original release.

In recent years, some insects such as the yellow sugarcane aphid and the West Indian sugarcane fulgorid *Saccharosydne saccharivora* (Westwood) have increased. Tests are being conducted to determine whether these insects are vectors of sugarcane diseases such as mosaic and ratoon stunting.

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Summary of Advances in Fiber Crops Production in South Florida During the Past Twenty Years

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Any review of the production and harvesting of fiber crops in South Florida during the past twenty years is greatly facilitated by the considerable place this phase of our agricultural enterprise has been given in the programs of the Society during this period. Reference is, of course, particularly directed to certain bast fiber types such as ramie, kenaf and jute and to one of the hard or leaf fiber types known as sansevieria.

Thus, in 1947 a symposium was held on this subject at the Everglades Experiment Station at the same time that a Fiber Crops Laboratory was finished and made ready for use in cooperation with the U. S. Department of Agriculture as a necessary and important part of a joint research and development program on these crops that has continued to date. The structure was built and the program initiated at that time with the cooperation of the U. S. Department of Commerce, a fact that reflects the urgency of fiber crops production on a domestic scale even during the closing months of the war. This symposium was a part of the Annual Meeting of the Society held in West Palm Beach and was published in Proceedings Volume 8, (1947).

This general subject was again given extended attention in the course of the Eleventh Annual Meeting (1951) in West Palm Beach when nearly half of the program was given over to it and a full day of field inspection through the Everglades followed with visits to the Everglades Experiment Station, to Newport Industries at Canal Point and to the new project on kenaf that was being developed at that time with this crop by the Shawano Development Corporation on the Hillsboro Canal about 15 miles southeast of Belle Glade.

Then, again, there were three symposia on fiber crops included in the program of the past year which were organized as something of an international review of the subject. The report on this phase of the program occupies pages 228-365 inclusive of Proceedings Volume 18, 1958. In this series of meetings the "Hard" or "Leaf" fibers were discussed separately, of course, and in full contradistinction to the "Soft" or "Bast" fiber types. In view of all this it would scarcely seem necessary for a further review at this time *except* that certain quite promising developments have continued on through the past year which should be briefly included. This would seem especially true since it is beginning to appear that certain advances in the mechanization of the harvesting operation, particularly in the instance of ramie and kenaf, have brought us right up to the very edge of where we have wanted to be from the very beginning of efforts in this interesting and important field. Furthermore, a brief sketch of the overall progress in the development of these crops through this period of review might prove of interest, at least to some.

By way of simple orientation, therefore, the two broadly different fiber types will be grouped and discussed as "Hard" and "Soft" with much

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greater emphasis on the latter because of the striking advances that recently have been made in certain important aspects of the work with them and the much better outlook for their production under Florida and U. S. conditions than has hitherto existed.

HARD OR LEAF FIBERS

The so-called hard or leaf fibers are the typical rope and heavy twine types which have played such an important part in fiber requirements for these purposes in the past. In this general group much more study has been given to sansevieria than any of the others though small observation plantings have been made and maintained from time to time with sisal, henequen, furcraea, phormium, agave, yucca and even abaca. This has been with no serious recent thought as to the commercial production of any of them in Florida. The culture and outlook of these various types is reviewed in brief detail in Florida Bulletin No. 590 (1).

The improvement work with sansevieria has been particularly aimed at resistance to disease and cold, and to improvement in fiber quality as well as yield, all in relation to soil type and various cultural treatments such as drainage, weed control, fertilization, etc. (2). To date crosses of S. *trifasciata* with S. *deserti* have shown by far the greatest promise of any that have been made (3). While some very definite advances have been made in this improvement work with sansevieria, this field of study has not been developed with any serious expectation of commercial adaptability to Florida conditions particularly for reasons of high land values in areas even approaching climatic fitness and the ever-spiraling of labor costs, upward. They are certain to have very obvious application, however, in areas of natural adaptability for the crop elsewhere in the Western Hemisphere (4) (5).

In the matter of harvesting the hard fiber types, Mr. Byrom and his associates in USDA at the Everglades Experiment Station have developed quite an efficient raspardor unit, a hand-fed (entire crowns), field-portable type, for the decortication of the stiff leaves of *Agave lechuguilla*, the rugged and thorny desert plant of the arid southwest, which produces superior fiber for certain kinds of brushes. This machine was reported on at the Annual Meeting of the Society last December (6) as was also another for the mechanical harvesting of sansevieria (7). In the latter instance this would be in contrast to selective harvesting by hand only of those leaves which are mature and ready for decortication. Its ultimate use in countries where sansevieria is definitely adaptable from the standpoint of soils and climate shall have to be determined by the purely economic factors of prevailing labor costs in relation to the natural advantages of selective (hand) harvesting, perhaps, in this instance, along with the use of a field decorticator with long but light conveyor-belt arms that will extend out over a predetermined width of the crop and facilitate the activities of the laborers as they move thru the dense growth and pull or cut selected leaves in the course of the harvest by moving the leaves to a small decorticator to which they are attached for this purpose in a central alley.

SOFT OR BAST FIBERS

Of all the soft or bast fiber plants studied in South Florida as a potential source of this important type of natural fiber—ramie, kenaf, jute, flax,

hemp, *Crotalaria juncea* (sunn hemp) and numerous others, the first two mentioned, ramie and kenaf, and particularly ramie, offer by far the greater promise for commercial development under South Florida conditions. The former furnishes a fiber that is often referred to as of super-linen quality and usefulness while the latter is a quite low-priced type and regarded largely as a very satisfactory substitute for jute. This, of course, still will find for it a very important place in our economy as well as that of the entire Western Hemisphere if ways and means can be found for harvesting the crop and processing the fiber to the spinning stage by methods that are economically feasible under our conditions.

A—*Ramie*

The first plantings of ramie at the Everglades Experiment Station were made in 1929 and maintained through the years but were given little systematic attention until quite some time later. However, it was soon obvious that, given good water control—a real "must"—and a reasonable level of fertility this crop is truly a "natural" for the organic soils of this area especially since *Boehmeria nivea*, the silver underleaf type, has never shown itself seriously vulnerable to any type of insect or disease attack, including the root-knot nematode. In general its cultural handling, as a perennial, is quite simple—rootstock planting in rows about 3 feet apart and at 1½-2 foot intervals in the row. With an early spring planting and midsummer mowing a light first harvest can be taken in the fall when the growth will have expanded well toward the closing of the rows to a solid stand. Since it is a perennial it will be ready for three harvests the following year and from then on thru undetermined periods of at least 7 to 10 years depending on cultural conditions and good rehabilitation practices. Much detail in this regard is given in Florida Bulletins 412 (8) and 525 (9).

Plantings were maintained and studied at the Everglades Station in a more or less routine way until the 1943-44 season when Newport Industries, Inc. of Pensacola moved their small project with this crop from Atmore, Alabama to the Everglades where it was steadily developed into the first ramie production project in America, having reached a total area of 2500 acres by 1956 when the work of this company was terminated. The manner of planting, harvesting and decortication throughout the life of the project are well described in USDA Agricultural Information Bulletin No. 156, 1956 (10). The average annual production of washed and baled fiber through the period of the operation of that project has been placed at approximately 1200-1300 pounds per acre.

The many mechanical problems encountered during the life of the Newport project, including the use of modified hemp binders for the harvest and the hauling of such tremendous tonnages of green material to a central Krupp-Corona decorticating plant where as little as 3-4 percent of finished fiber was extracted from it, will not be discussed at this time. Perhaps it will suffice to say that the development of a field harvester-ribboner by a Louisiana firm was well under way and in fact two of them were given a considerable period of trial by the company before the project closed. In any event some of the advantages of this type of field harvesting have been pointed out and emphasized by the writer in a 1956 publication (11). Some of the unusual qualities of this remarkable fiber were recently discussed by Seale and Allison (12) as were also some of the harvesting and processing problems by Allison and Randolph (13) and

the outlook of the fiber in U. S. industry by Morton and Allison (14).

As a matter of record both of the first two self-contained field harvesting and ribboning units were converted to what we now refer to as the "twin-drum" type before Newport sold them to a private operator (Mr. Alex Ramey) who in turn built an additional unit (No. 3) of the same type with certain improvements, of course, and proceeded to harvest about 100,000 pounds of fiber with them from his own plantation of nearly 1000 acres located near Canal Point. This fiber was baled for commercial use following field decortication, simple washing and drying and has been declared completely satisfactory by a very particular buyer on the world market in comparison to that produced by Newport's heavy central unit with its heavy pressures and abundant washing during the process of decortication. The only pointed difference commented on by the buyer was that this field decorticated fiber gave a "yield" of 73 percent finished fiber upon degumming in comparison to one of about 75 percent from Newport's first grade product from the Krupp Corona which had practically become a standard in the world market for this fiber at the time the Newport Corporation closed its operation.

Continuing this study-sequence of experimental field harvester-decorticators on ramie in the Everglades area on through this critical period, the North Atlantic Kenaf Corporation, with headquarters in Havana, Cuba, purchased the three units referred to above and proceeded to have a fourth one built by the same engineer (Unit No. 4) who had redesigned and converted the first two units to the twin-drum form and built the third one of this same style from the ground up. This firm also proceeded to harvest about 80,000 pounds of ramie from Mr. Ramey's plantation largely with the first three units since the fourth was not finished in time to participate in this effort. As before, this fiber was sold to a foreign operator having heavy requirements and processed with complete success.

Since the Cuban firm was particularly interested in kenaf in Florida as well as elsewhere in the Western Hemisphere, numerous efforts were made at ribboning this crop with twin-drum unit No. 4. In fact it was largely for this purpose that this unit was built. However, it never proved nearly so successful on this crop as for ramie and on this account has been essentially abandoned for this purpose, at least for the present. The Corporation, in fact, has very kindly loaned Unit No. 4 to the Everglades Experiment Station for harvesting studies with ramie which it is hoped may be continued through the 1960 season.

Both the "chain" type cleaner on the harvester-ribboner and the "twin-drum" approach to field decortication, rather than merely ribboning, have been and are being developed following prototype studies by USDA workers at the Everglades Experiment Station. The former was described in considerable detail at a quite early stage of development in the joint report of USDA-FAES to the Department of Commerce pp. 96-120, 1948 (15). The latter is being shown in Fig. 1 (above) also at an early stage of development with the Cary type as "Unit No. 4" in Fig. 1 (below) in which twin drums have been substituted for the earlier chain cleaners by the North Atlantic Kenaf Corporation.

Advent of Pierce Florida Ramie, Inc.—Following the discontinuance of the Newport operation in the Canal Point area where the crop was being grown on about 2500 acres and decorticated in a central plant and where the degumming was being done in Clewiston for the limited domestic

Figure 1.—The twin drum ribboner of USDA in an early stage of development which recently has come into use for field decortication of ramie is shown above. Below this same approach is to be found in "Unit 4" harvesting ramie in Section 10 at the Everglades Experiment Station.

market that had developed up to that time, a local group was organized to take over the entire operation. Rather than make use of the harvesting and decortication methods that had been developed and proven to date by the older firm, the Management Board of the new enterprise chose to rely on a considerable departure from those methods by developing its own harvesters which produced little more than crushed stems, topped, from which a certain amount of the broken wood and pith had been "brushed" from the bottom ends by the field unit, Fig. 2 (above). These ribbons are then taken to a quite complicated cleaning device which can best be shown in the photo of Fig. 2 (below). Small bundles of these "ribbons," usually the equivalent of 3-4 stems, hang from firm grips about the periphery of the large, horizontally mounted wheel that is about 18 feet in

diameter and which, in turning, draws them thru a series of six high-speed cleaning wheels (fluted) horizontally mounted and with graded settings so that a complete cleaning, with plenty of water applied at each position, is attained. Each small bundle, after the first round, is mechanically reversed and passed thru the same process so that both ends of each one of them will be cleaned. Although the ribbons that emerge usually are in-

Figure 2.— (Above) Field harvester for ramie developed for Pierce Florida Ramie, Inc. by Mr. William Pierce of Belle Glade.
(Below) General view of Pierce cleaning wheel for cleaning ramie ribbons produced by the harvester pictured above.

deed well cleaned and the fiber is in good alignment, the fact that the bundles must be small, 1 to 1½ ounces dry weight, if such cleaning is to be attained and the wheel can not turn beyond a certain speed or the bundles will swing out and miss the mills entirely, makes for low production and consequently high fiber costs. This is especially true in view of the considerable amount of labor required for handling such an operation and the mechanical misses, pull-outs and tangling of the fiber that almost unavoidably accompany it. For these reasons the production of fiber with such a unit has been found to be intolerably slow, economically.

Continuing Work with the Field Harvester.—While the limited amount of study that has been given the "twin-drum" type of field harvester-decorticator has produced some very favorable results, adequate quantitative tests have not yet been made with it which will permit a direct comparison of its efficiency with the "chain-type" cleaning device that was used in the first two Cary units which were the first to be converted to the twin-drum approach. Careful measurements of this latter type (chain) at the Everglades Station have given a recovery of about 75 percent of the fiber in the field whereas the best that has been attributed to the central plant (Corona) operation has been about 50 percent or less. It should be clearly understood that the so-called "chain" type of harvester-ribboner produced only ribbons that had to be further processed before degumming whereas the expectations for the "twin-drum" type are that it can be used as a harvester-decorticator which will produce decorticated fiber in the field ready to be washed, dried and either baled for storage or degummed. The very great importance of continued studies in this field is readily apparent. The standard "chain" type of harvester-ribboner produced by the Cary Iron Works of Opelousas, La., which produced this yield is shown at work in Section 10 at the Everglades Station (Fig. 3) when these tests were made.

At the close of the period covered by this report it might be said that there is a very considerable interest in the ramie harvesting trials with

Figure 3.—The "chain" type Cary harvester-ribboner at work on ramie in Section 10 at the Everglades Station where about ¾ of the total fiber in the field was recovered as ribbons and handled in the manner shown by the 300 pound bundle lying on the ground.

the angled-drum unit built in West Palm Beach by the North Atlantic Kenaf Corporation that was briefly referred to last year in the symposium on soft fibers, Proceedings Volume 18, p. 365. Although this unit was primarily designed as a harvester-decorticator (not harvester-ribboner) for kenaf and is planned for early trial on this crop in Guatemala, some preliminary trials with ramie look very promising. A very general view of this first unit is shown in Fig. 4. There is little doubt that the availability of a really effective field decorticator for ramie—one that will harvest and deliver a high percentage (at least 75-80 percent) of the fiber in the field in good alignment and free of wood and most of the bark—is still the paramount need for the development of this crop under Florida conditions. By the above specification it is to be understood that the fiber as it comes from the field is ready for a light washing and drying before baling for shipment or degumming direct.

Figure 4.—First unit of a small, angle-drum type of harvester-decorticator developed by North Atlantic Kenaf Corporation on which early trials at decorticating both kenaf and ramie have shown promise.

B—Kenaf

Tests with jute and kenaf, on one scale or another, have been under way in South Florida for several years, the first planting of jute on Everglades peat having been made in 1928. It is only during the past 10 or 12 years, however, that such tests have become appreciably significant. Although both crops are very seriously attacked by the root-knot nematode, jute has been found so susceptible to other diseases and does so poorly on our mineral soils that most attention during the past few years has been given to kenaf. This more or less leaves the latter as the most promising substitute for jute that can be grown under our conditions.

Inasmuch as kenaf also is quite susceptible to certain stem and leaf diseases, as well as nematode attack, much attention has been given to improvement of crop resistance to both by breeding and selection (16). This has been with a considerable degree of success in the former, particularly against the ravages of *Colletotrichum hibisci*, which is commonly referred to as "tip blight"; also with some interesting indications of re-

sponse in the instance of the latter (17). Much of the work in Florida has been done with the very friendly cooperation of workers in Cuba where, as in many other countries in the tropical and subtropical belts of the world there is much interest developing in this crop as a source of fiber against a possible failure of present supplies of jute, for one reason or another, particularly since our enormous requirements and those of other countries in the Western Hemisphere must find its way to us from India and Pakistan, both countries involving sea transportation from ports located nearly half way around the world.

Until very recent times when several interests in Cuba, Salvador and Guatemala began to process crude kenaf ribbons by a batching procedure which permitted their direct handling thru the spinning process by a method that has come to be known as "coarse spinning," it was thought necessary to ret the ribbons by way of preparation for spinning just as is done with jute stems in Pakistan and with both jute and kenaf in India. This, of course, would be prohibitive under conditions of Florida labor costs though not so critically so in certain other countries of the Western Hemisphere (18).

The matter of cost in the preparation of kenaf for spinning has been further relaxed, at least in prospect, during the past couple of years, thru the progress that has been made in the development of field harvesters that will decorticate the fiber rather than merely ribbon it, just as has been discussed for ramie. If this can be done on a field scale by the machines that are now in process of construction and testing, both privately and at the Experiment Station, it will permit the spinning of much finer numbers with such decorticated (though unretted) fiber following proper batching.

During the past year much interest has been gathering around a really heroic project that already is quite well advanced in its development around the good prospects of successful kenaf culture in Guatemala. Reference is to a completely modern spinning and weaving mill that has been built by Productos de Kenaf, S. A. at Escuintla and which is soon to be dedicated and opened for routine operation, at first largely with jute, of course, but with progressively more kenaf each year until in about 5 years it is definitely expected to be operating fully on kenaf. It is equipped with 12 circular looms for the weaving of heavy duty bags (coffee, sugar, etc.) from the comparatively coarse yarns which must be spun when crude ribbons are used with only a preliminary batching. As already mentioned, if decorticated fiber such as has been described above becomes available in volume this will permit the spinning of much finer numbers from such field fiber, still without prior retting.

This new project in Guatemala is of wide hemispheric interest since it is pioneering in a field of fiber source (kenaf) that can well find its way into other American mills and thus develop an insurance against failure in supply due to the vicissitudes of international politics and the trade confusions that may follow. It is against such conditions that we have been looking for some form of adequate protection for a very long time.

It would seem quite timely, therefore, that such a progress report as this should close with something of a hope and even a prayer for the best of success to Mr. Fred H. Sherwood and his associates in "Prokesa" down at Escuintla in their arduous undertaking. As one of our far-seeing Congressmen has so well said, the full success in the development of kenaf and the mechanization of its harvesting and processing to the spinning level down there could well bring the production of this vital fiber source into

the Cotton Belt of the Southeastern States where many thousands of acres of land satisfactory for its culture are yawning for such a cash crop due to the comparatively sudden migration of so much of the cotton acreage of this section to the southwest.

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TWENTY YEARS OF PROGRESS IN CONTROLLING PESTS OF FLORIDA FIELD CROPS

Weed Control In Pastures With Sandy Soils In Peninsular Florida[1]

J. E. McCaleb and E. M. Hodges[2]

The control of weeds has been of utmost importance to the human race since land was first used for agricultural purposes. Plants are found throughout all inhabited areas of the world and most species can be termed useful or harmful depending on the locality. For an example, pangolagrass is an important forage plant in improved pastures in central Florida but an undesirable plant, a "weed," in nearby citrus groves.

Scientific study on weed control began at a late date. Perhaps the first basic investigation was the buried-seed experiment started by Beal at Michigan State in 1879 which showed a range in viability among various species from a few months, to years and up to half a century. Studies by other workers have shown that periods of dormancy for a species are influenced by oxygen, moisture or temperature, and further, that plowing, mowing, and cultivating modify the environment and are often effective control measures. The purpose of many of the early inventions and developments of farm implements was to control weeds. Intensive weed control research directed toward solving practical problems is a recent development, starting in 1935 with the formation of a weed project by the Bureau of Plant Industry, USDA.

The use of chemicals for weed control was slow in starting. Copper salt solutions were used in 1897 to kill weed seeds in grain crops. Iron sulfate, sodium chlorate, sulfuric acid, sodium arsenite and others were tried in the years immediately following with moderate success in the same area of study. Bolley in North Dakota, after completing 12 years of research using sodium chloride, iron and copper sulfate and sodium arsenite, was greatly impressed by the possibilities of chemicals for general weed control. Soil sterilization studies were first reported in 1899, primarily with sodium arsenite. The next group of materials used for this purpose included chlorates, borax, and carbon bisulfide. A much needed impetus was given to chemical weeding in 1938 when French workers released Sinox (4,6-dinitro-o-cresol, sodium salt) which killed many broad-leaved plants on contact without injuring the grasses. This discovery led to increased efforts in this field and to re-evaluation of many other known chemicals. During this same period organic chemists were studying plant hormones or "growth regulators." The major advance in the field came in 1944 when 2,4-D (2,4-dichlorophenoxyacetic acid) showed its plant-killing properties. Later investigations proved it to be a selective plant killer of wide adaptability on broad-leaved species. Following the discovery of 2,4-D, many new chemicals were developed which were highly selective in nature, but grass and grasslike plants were mainly unaffected by these compounds. Several

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herbicides were released in the early 1950's to experimental workers for evaluation as systemic or translocated control agents for these resistant plants. These compounds, used separately or in combination with those selective for broad-leaved species, increased the overall effectiveness of chemical weed control and made its use feasible on pastures in peninsular Florida.

Chemical weed control programs in pastures on sandy soils in peninsular Florida are comparatively new; however, this phase of forage production is receiving more attention each year because of the increased cost of grazable lands, improvement of cattle by breeding, establishment of purebred herds and the increasing use of high producing grasses and legumes. The majority of noxious plants in flatwoods pastures are perennial weeds and grasses or woody, understory brush species. Annuals occupy disturbed sites in dense stands and may be serious when toxic or otherwise harmful to livestock, but in most instances competition by perennials and or mechanical methods control these invaders. In contrast, the perennial weed and brush species are relatively hard to control and usually require higher rates, more expensive herbicides, and two or more applications in a growing season. Mechanical methods used in addition to chemicals frequently give more effective control than either method above. The optimum dates for applying chemicals in spring and fall also coincide with maximum growth or production of nearby vegetable and citrus crops.

Study of Florida Agricultural Experiment Station Annual Reports, Southern Weed Conference Proceedings and other pertinent publications reveals that trials to control weeds in pastures have been given more attention each year since 1950. Information available prior to that date was mostly concerned with control of noxious plants in horticultural and field crops. An increasing number of tests is being made each year to determine the effect of herbicides on native species in this area. These trials include: new liquid formulations; granular or pelleted materials; inverts; stickers and or spreaders; techniques of application; carrier ratios of water and other materials; application methods; advances in means of evaluating results.

The following chart lists the plants which often are undesirable species in native and improved pastures in central Florida. Also shown are the herbicides, plant response to these chemicals and literature references giving materials which are currently accepted as controlling agents for the species. Rates per acre of herbicide, volume of carrier agent, and method of application are not given because weed maturity, season of year, proximity to desirable crops, and climatological factors must be considered. Herbicides other than those listed also may result in satisfactory control in many circumstances, and may be even more desirable when the many factors involved are given full consideration. It is beyond the scope of this paper to list all herbicides available or effective in controlling these plants. Study of the references, the Southern Weed Conference Proceedings in particular, will result in a fuller understanding of the trials and materials which are being tested and suggested for control of specific plants. The percentage plant kill, or control, which is satisfactory varies with plant species and management programs. In pastures 100 percent control may be unnecessary and excessively expensive.

The list of noxious pasture plants in pastures on sandy soils in peninsular Florida which can be controlled with herbicides has increased each year since World War II. Experiments must be continued to improve the

PLANTS, GROWTH CLASSIFICATION AND RESPONSE OF COMMON WEED SPECIES TO SELECTED HERBICIDES IN PASTURES ON SANDY SOILS IN CENTRAL FLORIDA.

Name and Classification[1]		Herbicide[2]	Response[3]	Reference[4]
Aster (Aster spp.)	P	2,4-D	I	4
Black-eyed Susan (Rudbeckia serotina)	P	2,4-D	I	4
Caesar-burr (Urena lobata)	P	2,4-D	I	4
Dog fennel (Eupatorium capillifolium)	P	2,4-D	I	1,2,3,4
Dollar weed (Dichondra carolinensis)	A	2,4-D	S	4
Elderberry (Sambucus simpsonii)	P	2,4-D; 2,4,5-T	I	4,24
Milkweed (Asclepias spp.)	P	———	—	———
Nettles, stinging (Urtica spp.)	P	2,4-D	I	4
Pigweed, red-root (Amaranthus retroflexus)	A	2,4-D	S	4,15,24
Pigweed, spiny (Amaranthus spinosa)	A	2,4-D	S	4,8,15,24
Pokeweed (Pokeberry) Phytolacca americana)	P	2,4-D	I	4,24
Primrose willow (Jussiaca spp.)	A	2,4-D	S	4
Ragweed, common (Ambrosia artemisiaefolia)	A	2,4-D	S	4,20
Sesbania (Sesbania macrocarpa)	A	2,4-D	S	4
Smartweed (Polygonum pennsylvanicum)	A	2,4-D; 2,4-D+2,4,5-T	I	4,8,24
Teaweed (Sida spp.)	P	2,4-D; 2,4,5-T	I	8,24
Thistle, bull (Cirsium spp.)	B	2,4-D	S	4,24
Water hyacinth (Eichornia crassipes)	A	2,4-D	S	13,18,24
GRASSES AND GRASS LIKE PLANTS				
Bahiagrass (Paspalum notatum)	P	Da; ATA	S,I	6,19
Bermudagrass (Cynodon dactylon)	P	Da; ATA; erbon	S,I	1,5,6,11, 12,21
Carpetgrass (Axonopus affinis)	P	Da	S	6,11
Cattails (Typha spp.)	P	Da; ATA; Da+ATA	S	19
Cogongrass (Imperata cylindrica)	P	Da ——	—	24
Cordgrass, Bakers (Spartina bakerii)	P	Da; Urox	S,I	4,24
Pangolagrass (Digitaria decumbens)	P	Da; ATA	S,I	3,6
Rush, common (Juncus effusus)	P	2,4-D	S	14,23,24
Sawgrass (Maricus jamicensis)	P	Da; ATA	I	22,24
Sedge—watergrass (Cyperus spp.)	A-P	ATA; 2,4-D; Mbr	I	21
Smutgrass (Sporobolus poiretii)	P	Da; Urox	S	1,6,24
Torpedograss (Panicum repens)	P	Da; ATA	S,I	6,19
WOODY PLANTS				
Blackberry (Rubus spp.)	P	2,4,5-T	S	2,3
Gallberry (Ilex glabra)	P	2,4,5-T	I	17,24
Persimmon, Eastern (Diospyrus spp.)	P	2,4,5-T; 2,4-D	S,I	5,10,24
Prickly pear (Opuntia spp.)	P	2,4,5-T	I	16
Saw palmetto (Serenoa repens)	P	2,4,5-T; 2,4,5-T +2,4-D	I	3,7,9,16, 24
Wax myrtle (Myrica spp.)	P	2,4-D; 2,4,5-T	I	16,24

[1]A=Annual; B=Biennial; P=Perennial.

[2]2,4-D=2,4-dichlorophenoxyacetic acid; 2,4,5-T=2,4,5-trichlorophenoxyacetic acid; Da (dalapon)=2,2-dichloroproponic acid; ATA (amitrol)=3-amino-1,2,4-triazola; MB=Methyl bromide; Urox=3-chlorophenyl)-1,1-dimethylurea trichloro-acetate; erbon=2 (2,4,5-trichlorophenoxy) ethyl 2,2-dichloropropionate.

[3]S=usually quite susceptible; I=usually susceptible at higher rates or with repeated treatments.

[4]See Literature Cited.

effectiveness of use of herbicides now available and to evaluate new compounds. This will help to meet the greater demands for agricultural products and to combat the constantly shifting weed populations which result from an intensified control program.

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Chemical Weed Control In Agronomic Crops On Florida's Organic Soils[1]

J. R. ORSENIGO[2]

The immemorial objective of cultivation in crops has been control of competing plants, weeds. Although agriculturists have reckoned the direct expense of hand and mechanical weeding, less emphasis has been placed on the vital competitive influence of weeds in crop production. National annual losses attributed to weeds and brush have been estimated at $3.2 billion in 58 major crops, $500 million in grazing lands, and $75 million in small grains underseeded to legumes (8). Intensified research during the wartime period of the 1940's appraised the role of chemicals in plant regulation and destruction and developed the now ubiquitous 2,4-D. During the past twenty years, myriads of chemicals, simple and complex,

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[3]Insofar as possible, herbicides are designated by accepted common names. Experimental designations are used for some materials. Unless specified otherwise, application rates indicate acid equivalent for phenoxyacetic acid materials and active ingredients for other herbicides. Dalapon and TCA herein imply use of the sodium salt formulations.

have been tested for pesticidal value. Many selective and nonselective herbicides have been developed and improved to become part of a new rational attack on weeds in crops alone or in combination with cultivation.

Sugarcane: Sugarcane is the most extensively grown agronomic row-crop on Florida's organic soils. Multiple-row tillage implements cultivate these level, stonefree, and friable soils effectively and economically.

According to Bourne (4), control of grass weeds in sugarcane fields is simplified by proper land preparation. Plant cane is tilled mechanically with three-row units mounted on crawler tractors; tined scratchers weed the sugarcane drill while harrow discs weed the row middles. Row middles are usually cultivated with rototillers in ratoon crops. To offset the ease and economy of mechanical weeding, chemicals must compete in special situations viz., specifically against problem weed species, efficacy against seedling and mature established grasses, and adaptability at and after lay-by.

Research in chemical weed control, especially in sugarcane, was implemented greatly when the United States Sugar Corporation established a grant-in-aid with the University of Florida Everglades Experiment Station in 1952 (7). Valuable information on the responses of crop plants to 2,4-D and the roles of volatility and drift in 2,4-D injury to sensitive crops was obtained by Guzman (7, 11, 12, 16). Toxicity symptoms were established for root and/or foliar application of serial concentrations of 2,4-D to cabbage, celery, cotton, kenaf, snapbean, and tomato. Both intensity symptoms and plant recovery were recorded. In confined atmosphere experiments the diethanolamine and dimethylamine salt formulations of 2,4-D were practically non-volatile at temperatures lower than 80 F, as measured by phytotoxic response in tomato plants. The low-volatile (long-chain, heavy) esters were intermediate in effect on test plants, while the isopropyl ester was most volatile and phytotoxic. Corn plants were sprayed with the dimethylamine salt of 2,4-D and placed in control chambers with untreated tomato plants. Tomato injury symptoms did not develop in chambers maintained at low temperature and low air movement (20 C and 5 mph). At high temperature and high air movement (40 C and 12 mph) severe injury was recorded, while intermediate symptoms developed under intermediate conditions (27 C and 8 mph). Most plants recovered and grew normally after field transplanting.

Guzman (7, 11, 12, 16) continued the assessment of 2,4-D drift and volatility injury in many series of field experiments with ground and aerial application equipment. With the dimethylamine salt of 2,4-D most crop injury appeared to result from physical drift of spray materials during application. Volatilization and vapor drift subsequent to spraying appeared to induce a relatively minor degree of sensitive crop injury and appeared to be influenced by wind direction and velocity. Aeolian movement of 2,4-D-contaminated surface soil and dust may have been responsible for more injury than volatilization and vapor drift. The influence of the major factors contributing to injury, wind direction and velocity, air and soil temperature, was mitigated in most experiments by use of the dimethylamine salt formulation. From these experiments the following operational "rule-of-thumb" was developed: "Formulation should be restricted to the dimethylamine salt of 2,4-D; sugar cane less than one-half mile from sensitive crops should not be weeded with 2,4-D except under

Figure 1.—Weeds resistant to 2,4-D (top) and to monuron (center) individually, were effectively controlled (bottom) when the two herbicides were applied in combination at the same rates (2,4-D, 1.5 lb/A, and monuron, 2 lb/A).

special circumstances of no wind or low air movement, when a one-quarter mile minimum may be used under careful, continuous supervision."

Many of the herbicides and herbicidal combinations evaluated by Guzman (7, 11, 12, 13, 14, 15) provided excellent control of grass and broadleaf weeds; however, many were not economically competitive with mechanical methods. The dimethylamine salt of 2,4-D maintained the best general control of broadleaf weeds: 1.0 lb./A was inferior to 1.5 or 2.0 lb./A. The rate of water carrier, 10, 20, 30, 40, or 60 gpa, in which 2,4-D was applied had no influence on yield of cane. Pellitory weed, *Parietaria floridana* Small, is difficult to control and may smother regrowth of stubble cane in the spring. The substituted urea herbicides, especially monuron, have given complete, specific control of this cool season infestant. Although the addition of 2,4-D to monuron tended to increase control of Pellitory weed (Figure 1), possible synergistic or additive mechanisms were not determined.

Adequate, economical control of annual grass weeds in sugarcane has been a serious problem. In early trials mechanical cultivation or a mixture of monuron and TCA were most effective, and commercial control was afforded by a mixture of 2,4-D and TCA. Generally, herbicide treatment plots yielded more cane per acre than mechanically weeded controls (13). In plant cane two post emergence applications of TCA (19 lb/A) plus 2,4-D (2.2 lb A) appeared to be economically profitable due to increased yields (14). However, TCA was being displaced by the grass herbicide dalapon, and in experiments with this newer material, 6.8 to 12.8 lb/A provided excellent grass control but severely stunted sugarcane and may have reduced yields at all rates. Subsequently, dalapon applied at 4.1, 6.4, and 8.5 lb A in water carrier rates of 30, 60, 90, and 120 gpa provided satisfactory grass weed control in all combinations, and the treatments did not influence yield of cane or of 96° sugar (15). Seedlings of annual grasses were controlled effectively by split dalapon applications totaling about 10 lb/A per season. Cane injury from dalapon was reduced and grass control impaired slightly when the total rate was divided among two or three applications. Chemical control measures applied soon after harvest when weeds were small, i.e., January-March, were more effective than late applications, i.e., April-May. Grasses especially were more readily and extensively killed by early sprays; one 4.2 lb A dalapon treatment killed grasses up to 3 in. tall, while a second application was required to kill seedlings from 3 to 8 in. tall (7, 12). Dalapon (4.2 lb/A) plus 2,4-D (1.5 lb/A) was one of the most effective herbicidal treatments. However, yield of cane and of 96° sugar were reduced by two applications of dalapon or TCA alone, or in combination with monuron, 2,4-D or both (17). Guzman (18) later reported that "Dowpon," the commercial formulation of dalapon, at 3 to 5 lb/A plus 2,4-D at 1.5 lb/A obtained effective grass and broadleaf weed control and did not affect yield of cane or 96° sugar adversely.

Additional experiments investigated the influence of rate, number, and method of dalapon applications on sugarcane. Dalapon (4.2 lb/A) and 2,4-D (1.5 lb/A) were applied twice as either broadcast-overall or directional sprays at three stages of cane growth. All treatments controlled seedling grass and broadleaf weeds satisfactorily and neither spray method nor stage of cane growth, at treatment, significantly influenced yield of 96° sugar. Cane yields were reduced when the treatments were applied late in the season (May) rather than one or two months earlier (19). The rate

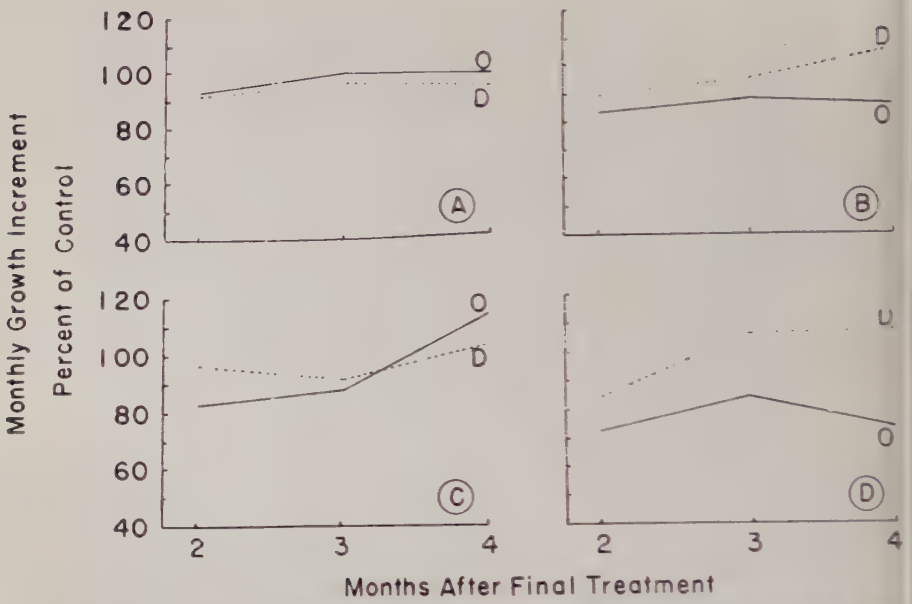

Figure 2.—Sugarcane growth increments as percent of untreated control at 2, 3 and 4 months after final application of dalapon: A, 3 lb A applied twice; B, 4 lb A applied twice; C, 3 lb/A applied three times; D, 4 lb/A applied three times.

The solid line represents overall spray treatment while the broken line indicates directed spray application.

and number of dalapon applications associated with optimal grass weed control and minimal sugarcane injury were investigated on stubble cane. Practical grass control was obtained with two 5 lb A or three 3, 4, or 5 lb/A treatments. Traces of cane injury were evident for two months after a single 5 lb A spray and for several months after two or three 3 or 5 lb/A applications. In the first harvest year, yields of cane and 96° sugar did not differ significantly among the dalapon treatments and the mechanically weeded control (20, 21, 24). When continued for a second year, cane injury appeared more severe; yield of 96° sugar was reduced significantly by dalapon treatment (33).

An experiment still in progress has demonstrated the association of foliar application of dalapon and growth reduction. Typical responses in sugarcane growth rate after foliage overall and basal directed dalapon sprays are charted in Figure 2. Overall application of dalapon to the foliage invariably reduces the growth rate soon after application and this reduction is intensified by repeated applications. The deleterious effect of 3 lb A applied overall two or three times diminishes in several months after the final treatment. Cane growth rate continues to be affected markedly four months, and longer, after two or three overall applications of 4 lb A. Basally directed dalapon applications which avoid wetting the cane foliage are required to prevent injury (31).

Recently, 30 herbicides have been evaluated for sugarcane pre- and post-emergence, in some 125 single or combination treatments. Sugarcane appeared tolerant of almost all herbicides and combinations tested, es-

pecially in pre-emergence trials. Post-emergence applied amitrol plus either dalapon, FW-450, or simazin temporarily reduced cane growth and vigor more than other treatments. Visible deleterious effects rarely persisted more than two months after application. Injury symptoms were most apparent soon after treatment and persisted longer when conditions for cane growth were poor. Certain chemicals were promising grass herbicides and are being tested further (24, 25).

Pasture and range: More acres of organic soil in Florida are devoted to pasture and range than to all other agronomic crops. Approximately 135 sections (85,000 acres) carry about 100,000 head of cattle.[4] Probably the greatest need for weed control is during establishment of pasture grasses. Later good pasture management will provide the most economical control of weeds. Under proper grazing load, adequate fertilization plus occasional, timely mowing will assist adapted pasture grasses to compete effectively with weeds.

Seale, *et al.* (39) reported that pasture grasses from 3 to 6 in. tall could be weeded with 0.5 to 1.0 lb/A of 2,4-D. They also stated that well established stands of St. Augustinegrass, Pangolagrass, Bermudagrass, Paragrass, and Caribgrass could be treated safely with 1.0 to 1.5 lb/A of 2,4-D.

Mowing was relatively ineffective in weed control in continuously grazed pastures of ryegrass and rescuegrass alone or with legumes. Broadleaf weeds were controlled by spraying 2,4-D on burlap bags, draped from the sprayer boom, which were then dragged over the weeds. Legume injury was slight (1). MCPA is the preferred herbicide in pastures which contain legumes.

Reports of the tolerance of St. Augustinegrass to 2,4-D conflict and indicate incomplete knowledge of the factors which influence response to this herbicide. In one situation, this grass was killed by 2,4-D; neither rate applied or other details are given (3). In another instance, the bitter blue strain was killed and several other strains were damaged severely (37). Seale (36) reports that the amine salt of 2,4-D at normal weed control rates had no lethal effect on Roselawn St. Augustinegrass or other pasture grasses. In more recent trials St. Augustinegrass injury was slight and temporary following application of 1.5 lb/A of the amine salt or of a low-volatile ester of 2,4-D. The butyric acid analog, 4-(2,4-DB), is effective against many broadleaf pasture weeds and is non-injurious to St. Augustinegrass at herbicidal rates (32).

Several treatments were effective in renovation of bermudagrass pasture: TCA at 80 lb/A followed by harrowing, or dalapon at 25 lb/A without harrowing. A split application of dalapon was superior to a single full-rate dose. Allen and Guzman (2) also reported excellent control of Paragrass with 10 lb/A of dalapon.

It is difficult to estimate accurately the acreage of organic soil reserved for sod production and the annual removal of sod for landscaping purposes. Cattle are grazed during the development of many sod fields. Customarily, only post-emergence herbicides are applied to sod; 2,4-D is used most commonly although 2,4,5-T may be combined as needed to control woody or 2,4-D-resistant species. A recent primary evaluation trial in new and established sod has illustrated the promise of two herbicides, simazin and 4-(2,4-DB), in sod production (32).

[4] Allen, R. J., Jr. and F. T. Boyd. Twenty years of pasture development in the Everglades. Proc. 19th. Ann. Mtg. Soil and Crop Science Society of Florida. 1959.

Butterweed, *Senecio glabellus* Poir., an alkaloid-containing plant has been implicated in cattle deaths in the Everglades. Apparently, cattle graze this winter-spring annual in the immature rosette stage and reject it when in flower. Terminal symptoms are similar to "walking-disease" associated with other *Senecio* species (22, 23). This plant may be controlled inexpensively with the following herbicides: MCPA, 2,4-D, 2,4,5-T, and (2,4-D + 2,4,5-T). The relationships between plant growth-stage and alkaloid content are under investigation (29).

Field Crops: Field crops have been grown to a limited extent on organic soils. Generally, plantings of field corn are weeded satisfactorily with conventional tillage tools. Field corn has been grown successfully on a demonstration basis with a pre-emergence application of DNBP or CDAA and tilled only at lay-by hilling. Broadleaf weeds may be controlled economically without crop injury by post-emergence application of 2,4-D at 0.5 to 1.0 lb/A. This herbicide should be sprayed below the leaf canopy before plants exceed 12 in. in height (37, 39).

Broadleaf weeds in rice three to four weeks of age have been controlled with 2,4-D applied at 0.5 to 1.0 lb/A (39).

Annual weeds in soybeans on the peat soil of the Zellwood area have been controlled effectively until lay-by with pre-emergence applied CDAA, 4-6 lb/A; CDEC, 4-6 lb A; EPTC, 6-10 lb A and sodium salt of PCP, 10-15 lb/A. These herbicides did not affect crop growth or yield (35).

Periodic evaluation trials of pre- and post-emergence herbicides at the Everglades Experiment Station include several field crops, viz., field corn, oat, rice, sorghum, and soybean (25, 26, 28). Certain promising herbicidal treatments have been selected for each of these crops and will be available for advanced testing and field use when warranted.

Fiber crops: Commercial production of fiber crops on the organic soils of the Everglades has been exploratory and variable. Plantings of ramie, the most important of these fibers, have fluctuated from about 2500 acres to the current level of some 600 acres. Apparently, weeds are controlled adequately at relatively low cost with mechanical equipment. New plantings are established with frequent, careful use of multi-tined scratchers at about $0.25 per acre per scratching (5). Five to eight cultivations are supplemented with hand or spot hoeing until the plants are large enough to shade the soil and weeds (5, 6). Row cultivation may be used if needed. Ordinarily, no cultivation is required after establishment (5, 6). Broadleaf weed infestations in ramie may be controlled with 2,4-D (amine salt, 1.0 to 1.5 lb A.). This treatment is most effective when applied before "staging" winter growth. Vegetative growth is retarded for a short period but recovery is rapid and neither yield nor fiber quality appear to be affected (36, 38, 39).

Certain herbicidal materials have been used successfully as defoliants prior to mechanical harvesting of ramie. In commercial practice 80 per cent defoliation has been attained within 48 hours after aerial application of endothal. Calcium cyanamid and PCP were inferior to endothal (5). In recent experimental treatments endothal at 6 lb A provided more rapid and complete defoliation than KOCN or DNBP (30).

Sansevieria, a fiber plant grown more extensively as an ornamental, has been weeded successfully on both coastal sand and organic soils with substituted urea herbicides. Monuron at 5 to 10 lb A has maintained two

to four months of satisfactory weed control without crop injury (9, 10). A shift of weed infestants, especially grasses, accompanied repeated use of substituted urea herbicides on the coastal sand soils of the lower east coast of Florida. Certain genera, notably *Chloris* sp., have survived under periodic applications of monuron (40). Several post-emergence herbicides which will control monuron-tolerant grass species have been evaluated on a limited scale. *Sansevieria* tolerance to some treatments is sufficient to warrant further testing (34). Growth and yield of this crop were not affected by 2,4-D at 0.5 to 2.0 lb A or by the ammonium salt of DNBP at 2 or 4 gpa. Aero cyanate controlled weeds in *Sansevieria* and caused little damage. The sodium salt of TCA and several other herbicides caused injury (36).

Weed control in kenaf has not been investigated completely. However, this crop is included regularly in primary herbicide evaluations at the Everglades Experiment Station and appears amenable to a pre-emergence chemical weed control program (25, 26, 28).

Summary and present status: The relative ease and economy of mechanical tillage have limited adoption of chemical weed control practices among the few agronomic row crops grown on organic soil.

Research by Guzman (7, 11, 12, 16) developed valuable information on the relationships between 2,4-D formulation and plant toxicity, and also evaluated the roles of 2,4-D drift and volatility in field injury to sensitive plants. Physical spray drift during application operations was judged the major cause of injury. Dalapon injury to sugarcane has been investigated by Guzman and Orsenigo. Recent research by the latter demonstrates the marked deleterious effect of foliar applications on plant growth, while basally directed sprays are relatively inocuous. Agronomically adequate herbicidal treatments have been developed for sugarcane; however, these chemical methods do not appear to be generally competitive with mechanical weed control. Current research problems include the development of more economical herbicides or means of using existing materials more effectively as well as evaluation of recently developed herbicides.

Approximately 100,000 pounds of 2,4-D are used annually for the control of broadleaf weeds on some 30,000 acres of sugarcane on organic soil. Actually, new formulations of 2,4-D have given adequate weed control at lower rates of acid equivalent than formerly. Bourne (4) reports that less than 2 lb/A of the dimethylamine has replaced the earlier usage of 3 to 4 lb/A of the sodium salt of 2,4-D. Dalapon is used on a relatively limited scale on some plantations for the control of grass weeds in sugarcane. Monuron, alone or with 2,4-D, is used principally for the control of Pellitory weed. Undoubtedly, herbicide usage in sugarcane will increase in pace with rising labor costs and as new herbicides or methods of use are developed.

Sufficient information is available to support the general use of 2,4-D for control of broadleaf weeds in most pasture situations. More information is needed on the factors influencing St. Augustinegrass response to 2,4-D. In recent trials injury has been negligible or relatively slight and recovery prompt. Other selective herbicides probably will be developed to displace 2,4-D for this use. Sod establishment may become simpler with the development and adaptation of grass-tolerant pre-emergence herbicides. Commercially, insufficient use is being made of rudimentary weed control

practices in pastures, mowing as required supplemented by applications of 2,4-D alone or with 2,4,5-T to control broadleaf and woody weeds.

Little research has been devoted to the chemical weeding of field crops. Field crop acreage is small and weeds are generally controlled adequately with cultivation equipment supplemented with 2,4-D. Effective, economical herbicides for use in certain field crops have been evaluated in chemical screening trials and this information is available for development if field crop acreages expand.

Chemical weed control methods have not been adapted to fiber crop production on a great scale. Certain herbicidal applications are commercially usable. Research information has been acquired for future development in several crops.

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Figure 1 is assembled from research photographs of Dr. V. L. Guzman. Figure 2 drawn by Mr. E. King.

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Weed and Brush Control In North Florida[1]

E. G. RODGERS[2]

The use of chemicals, or herbicides, for weed control purposes is not a new practice, although by far the greatest advances in this field have occurred during the last 10 to 15 years. At the end of World War II, accepted weed control practices were largely mechanical and cultural in nature. But more than 100 million pounds of herbicides were used on more than 35 million acres of cropland in the United States in 1959 for weed control purposes. Concentrated research efforts by the United States Department of Agriculture, state agricultural experiment stations, and the agricultural chemical industry have been responsible largely for these significant strides during a short span of years.

Considerable research effort is essential in the development of a satisfactory chemical weed control practice. For this practice to be acceptable, a chemical must be selected and applied at a rate or concentration that will kill a large portion of the existing weed population. And if the weeds to be controlled are growing in conjunction with or in close proximity to crops or other domesticated plants, the herbicidal treatment must not damage these plants. The development of a practice that will meet these two criteria, therefore, usually requires a long period of testing numerous compounds each at many concentrations on many weeds and desirable species, since considerable variations exist between any two herbicides in phytotoxic effects on commonly existing weed and crop plant populations.

Plant selectivity, or the ability of one plant species to survive a given herbicidal treatment while another species is killed, is important in the use of herbicides but is not understood. Crafts (10), however, listed differential wetting and morphological features as contributing factors. Highly cutinized leaves are more difficult to saturate with a chemical spray and thereby more tolerant to herbicidal treatment than other leaves. Legumes and other plants with meristematic tissues relatively exposed at the tip or in leaf axils usually are more easily killed than grasses and similar plants that have well protected meristems. Physiological factors and genetic makeup of plants also are believed to play important roles in selectivity.

The purpose of this paper is to review weed and brush control developments related to agronomic crop production that have occurred in north Florida or have exerted their influence in that area.

WEED CONTROL IN CROPPING AREAS

Many different weed species abound on cropland in north Florida. Among common broad-leaved weeds that compete with crop plants are Mexican clover (Florida pusley), Lambsquarters, diodia, eyebane, cocklebur, coffeeweed, pigweed, ragweed, smartweed, and Spanish needle. Two of the principal narrow-leaved annuals are crabgrass and sandbur. Nutgrass and such perennial grasses as bermudagrass infest many acres of crop-

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land and wherever such weeds are found, more intensive control measures are necessary than for annual weeds.

Weeds have been controlled in cropping areas for generations largely by conventional cultivation and hoeing. These methods were satisfactory so long as an abundant supply of cheap labor was available. But a marked decline in available labor and sharp increases in labor prices during and since World War II stimulated investigations in the use of herbicides as a means of reducing the required labor in crop production. In some crops, the necessity of hoeing has been eliminated and the amount of required cultivation reduced by the use of herbicides. These developments have alleviated the increased costs and reduced supply of labor and in several cases, reduced the cost of production.

Peanut Fields

Among the first workers using chemicals for weed control in peanut fields were Scholl and Searcy (29) in Alabama. They reported that pre-emergence applications of 2,4-D showed promise of controlling most annual weeds that compete with peanuts. Searcy (30) continued these investigations and reported that dinitro compounds applied pre-emergence were among the most effective chemicals tested. Florida workers (16) generally agreed with Searcy on this point.

Witherspoon and Rodgers (32) reported in 1954 that early post-emergence applications of 4,6-dinitro-ortho-secondary-butylphenol (DNBP) were more effective in control of annual weeds than pre-emergence treatments. They stated that three pounds of active ingredient per acre gave excellent weed control for 12 weeks with no serious injury to peanuts, while rates as high as nine pounds per acre pre-emergence controlled weeds for no longer than four to six weeks.

This work, substantiated by later tests in Florida as well as in other peanut growing states, lead to development of recommendations by Rodgers, Burt, and Mixon (28) for both pre-emergence and post-emergence applications of Premerge (DNBP) for weed control in Florida peanut fields. These workers stated that considerable reduction in cost of the chemical could be realized by treating a band 12 to 15 inches wide astride the row and controlling weeds in the untreated middles with conventional cultivation as required. These recommendations still stand in Florida, although 2,4-dichlorophenoxyethyl sulfate, or sesone, has shown good control on heavier soils and is presently recommended for use in peanut fields in Georgia.

Corn Fields

Probably a greater quantity of herbicides is used for weed control in corn fields in the United States than in the production of any other single crop. Most of this quantity is an amine salt of 2,4-D applied at about one-half pound active ingredient per acre when the corn is 6 to 18 inches high. Most common varieties of field corn will tolerate this treatment without serious damage and most annual broad-leaved weeds will be killed.

Specific research of this type conducted on field corn in Florida has been rather limited. Burt (6, 7, 8) found, however, that 2,4-D and post-emergence applications of DNBP were satisfactory for use on field corn in Florida. Simazine at rates as low as one and two pounds per acre also gave good control of annual weeds without injury to corn. Klingman and

Davis (18) in North Carolina stated that liquid nitrogen applied to growing weeds killed them effectively and also served as a source of nitrogen to stimulate growth of corn. This practice has been studied in various locations, but it has not been developed into a common practice. Use of the 2,4-D treatment remains most popular when a herbicide is applied in corn fields, particularly for control of annual broad-leaved weeds.

Soybean Fields

Weeds compete with soybeans for growth materials and often cause a reduction in yield of harvestable beans when only conventional methods of cultivation are used. Some of the first Florida work in using herbicides in soybean fields was done by Burt and Witherspoon (9) in 1954. They found that Cholor-IPC at pre-emergence rates as low as three pounds per acre effectively controlled most annual weeds and as high as nine pounds per acre did not seriously damage soybeans planted late in the season. Soybeans planted earlier in the season were damaged by all treatments. Burt (5, 7) compared these Chloro-IPC treatments with various other herbicidal materials and found Chloro-IPC to be among the most satisfactory. He (8) found later that sodium PCP at 8 and 12 pounds per acre had about the same efficiency as the Chloro-IPC treatments on Lee, Jackson, and CNS-4 soybean varieties. The general opinion at this time, however, is that Chloro-IPC applied pre-emergence at six to eight pounds per acre in 12" to 15" bands is among the best materials to use in the South for weed control in soybeans (21).

Small Grain Fields

Weeds normally do not pose a control problem as serious in small grain fields in North Florida as in the other crops mentioned above. Principal reasons are that small grains are close-drilled and compete satisfactorily with most weed species, a majority of small grain acreage is used for grazing purposes in which the presence of a few weeds is not considered serious, and the growing season is during the cool part of the year when most weed species are dormant. Some acreage of oats, however, is harvested for grain on which weeds may be a problem.

Burt (4) reported that ester or amine formulations of 2,4-D may be applied safely for weed control at one-half or one-half to two pounds per acre, respectively, when the oats were in the three- to four-leaf stage. The same formulations of MCPA gave less effective weed control. At present, however, the most widely used treatment of most varieties of oats is the amine formulation of 2,4-D at about one pound per acre (22).

Specific Weeds

Nutgrass (*Cyperus rotundus*)—Nutgrass is a sedge well adapted to a wide range of conditions. It abounds on cropland in north Florida after it is once introduced. Its growth habit of producing numerous prolific tubers at least to a depth of 24 inches in the soil (31) and the long period of viability retained by these tubers make this plant extremely difficult to control.

A satisfactory treatment would consist of thorough penetration of the soil to the depth of these tubers by a chemical with adequate phototoxicity to kill the tubers. No chemical is known that can meet these requirements under practical field conditions. Methyl bromide, a gas slightly heavier than air, applied under an air-tight cover at one to two pounds per 100 square

feet of soil surface area has given satisfactory nutgrass eradication (19). This treatment, however, is satisfactory only for use in plant beds or other similarly small areas.

Burgis (1) reported that the tops of nutgrass plants might be killed by 2,4-D applications at five pounds per acre. Harrison (14) stated that 2,4-D would kill some young tubers but would not affect old tubers. Cultivation efforts to sever the chain of tubers to stimulate output of new growth by each tuber is justified so that the top growth can be killed by 2,4-D. According to Hauser (15), combinations of 2,4-D and amitrol have been effective in this regard. Burt (2) found amitrol alone to be effective. The latter material is translocated more effectively through the tuber chain than 2,4-D or most other herbicides. Alternate plowing or discing combined with application of these chemicals at monthly intervals through the growing season may greatly reduce the stand in areas not being cropped (23). The application of 2,4-D at two pounds per acre may be made as required when the land is used to grow crops tolerant to this treatment.

Although considerable effort has been and still is being directed toward development of a satisfactory control procedure, no completely satisfactory method has been developed. Eptam and vapam, as well as amitrol, have shown promise in that direction. New herbicides continue to become available and this author believes that a new herbicide or a new formulation of some already existing chemical will be developed that will control this pest.

Another *Cyperus* species, *C. esculentus,* commonly called chufa, has been recognized in Georgia (15) as a serious problem on over 1,000,000 acres and has been noted in some sections of Florida. *C. esculentus* does not produce tubers as widely dispersed in the soil, but it does produce larger quantities of viable seed than nutgrass and thereby its distribution can become serious. Although this plant was once used widely for swine feed and still is grown on a limited basis for this purpose, it should not be grown as a crop on land not already infested with nutgrass.

Bermudagrass (*Cynodon dactylon*)—The presence of bermudagrass on cropland poses a real problem in the production of row crops. The stoloniferous, sod-type growth makes cultivation difficult. Tillage operations usually serve only to break the runners into smaller segments, each of which serves as effective propagative material.

Hansen (13) stated in 1924 that shading bermudagrass with a rapid growing smother crop was an effective means of reducing the stand of this grass. The problem was not actively studied until during the late forties when sodium trichloroacetate (TCA) was found to be an effective killer of perennial grasses when applied at approximately 40 pounds per acre. TCA is a corrosive material and is not absorbed by the plant as readily as dalapon, a killer of perennial grasses that has largely replaced TCA because it is taken into the plant more readily and is less corrosive. Dalapon at 20 to 25 pounds per acre kills practically all bermudagrass (3). Rodgers (24) found that dalapon in mixture with diuron was even more effective, but somewhat more expensive also.

Dalapon remains the most widely used herbicide for bermudagrass control. This material often is applied at the rate of five pounds per acre for three applications at intervals of 10 days to two weeks. Discing between applications seems to increase effectiveness. This method of split applications of dalapon has provided more effective control than a single application of a larger quantity of the chemical.

BRUSH CONTROL

Invasion of most undisturbed land areas by woody plants, or brush, is a natural process. Subsequent economic use of such areas usually requires that this brush be eliminated.

Many different plant species are considered as brush in the northern half of Florida. Several species of oak are among the most common, particularly Turkey oak (*Quercus laevis*) on the deep sandy soil types. On heavier soil types, sweet gum, hickory, and willow are representative species.

In most areas, brush to be controlled consists of several different species. In such instances, the most common herbicidal treatment consists of four pounds of a mixture of ester formulations of 2,4-D and 2,4,5-T in 100 gallons of water being sprayed until the foliage is thoroughly wet when vegetative growth is rapid, usually during spring months. When spraying plants having leaves with a particularly waxy or smooth cuticle, a small portion—usually not more than 10 gallons—of the water carrier may be replaced with diesel oil or some other oily substance to reduce the surface tension of the spray solution and thereby aid retention of the spray droplets on the leaf surface. This treatment is used widely on utility rights-of-way and in similar areas for brush control.

The brush in some areas consists of a highly dominant species with scattered plants of other species. For instance, Turkey oak is considered to be the dominant species on several million acres of sandy soil in Southeastern United States. In such areas, control measures obviously must be designed to control that one species.

Extensive studies have been performed in an effort to control Turkey oak with chemicals. In studies performed at Eglin Air Force Base, Florida, Rodgers (26) found 2,4,5-T or mixtures of 2,4-D and 2,4,5-T at rates as high as 16 pounds active ingredient per acre applied in the spring to provide not more than 75 percent control of Turkey oak, and even less effective control when applied in late summer or fall. Comparable silvex applications were only slightly more effective. However, three annual applications of iso-octyl ester of 2,4,5-T at three pounds per acre to Turkey oak sprouts gave satisfactory control. The substituted urea compounds monuron and diuron at minimal rates of 10 pounds per acre were the only single treatments to provide complete eradication. Since these materials are soil sterilants, the season of application was not an important factor in providing the desired control.

Woods (33) reported that monuron killed Turkey oak and bluejack oak at dosages of 11 pounds per acre as a soil treatment in the sandhills of northwestern Florida. He found that wiregrass (*Aristida stricta*) also was killed by this treatment, but that gopher apple, saw palmetto, cactus, beargrass, sassafras, and bracken fern were more resistant than the oak species to monuron.

Various other individual species offer control problems. Persimmon is relatively resistant to 2,4,5-T, but is somewhat more sensitive to silvex (25). Similar results have been secured by Darrow (11) in Texas. He found 2,3,6-TBA at rates as low as eight pounds per acre to give satisfactory control. This chemical, however, has been relatively ineffective in Florida (26).

Saw palmetto is difficult to control. Nation (20) reported that 2,4,5-T applied to the buds would effectively kill this plant. Some Florida work

(26) verified these findings in that three pounds per one hundred gallons of an oily carrier was the minimal effective rate. Apparently, covering the fronds with herbicidal spray is relatively ineffective unless the buds are thoroughly saturated. Even then, the plants usually require two or more seasons to decompose to the point that the land can be used conveniently without the necessity of heavy equipment to uproot the plants. When land is needed sooner than about two years, the better procedure is to use heavy equipment to uproot the living plants without the use of chemicals.

Most herbicides are applied as a spray using water, or an oil-in-water emulsion, as diluent, and some of the spray droplets may drift into areas not intended to be sprayed. The close proximity of crops or ornamental plants to many areas in which brush is to be controlled causes the drift hazard to be serious. In an effort to reduce the danger of crop or ornamental plant damage by these drifting particles, increased interest has been shown by some agricultural chemical companies in producing formulations of 2,4,5-T and related compounds designed to be sprayed in a carrier composed of water droplets enclosed in oil, or a water-in-oil emulsion. This water-in-oil emulsion is known as an invert emulsion (17). Individual droplets are heavier and usually larger than droplets of the oil-in-water emulsion, thereby reducing the drift hazard.

Herbicides may be applied for brush control purposes as a foliar spray, which is the method most commonly used for the treatments discussed above. However, Rodgers (27) outlined various other methods of using specific herbicides for brush control, including basal bark, stump, and frill treatments, and soil sterilization. Stumps should be treated within three days after cutting if the treatment is to be most effective. From 8 to 16 pounds of 2,4,5-T or related phenoxy compound per 100 gallons of oily carrier should be used. The same mixture is suitable for applying to the basal bark of a tree. The frill treatment consists of overlapping axe cuts around the base of the tree into which ammate, sodium arsenite, or the 2,4,5-T solution described for stump treatment may be placed.

The pulp and paper companies in north Florida are interested in chemicals for brush control. They have used numerous materials on a limited trial basis and have found in general the 2,4-D:2,4,5-T mixture is best for foliar applications to Turkey oak and mixed brush on sandy soils. Because of the vast acreages usually involved and the inaccessability of some of them, increasing interest has been shown in the use of aerial application (12). At least one such company has launched an extensive research program to control titi (*Cyrilla racemiflora*), an aquatic woody plant. This plant predominates many thousands of acres that may be successfully drained and used for pine production when a chemical treatment is found that will satisfactorily control it.

In conclusion, new uses for existing herbicides will be found and new herbicides will be produced in the future for still additional purposes as a combined result of research efforts by state, Federal, and industrial personnel. Great advances in the use of herbicides have been realized during the last decade, but even greated achievements can be expected during the next 10 years.

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Progress In Control Of Insect Pests Of Florida Field Crops During The Last Twenty Years

A. N. TISSOT[1]

Studying insect pests of farm crops and recommending control measures was one of the earliest functions of the newly established Florida Agricultural Experiment Station. The Station was set up in the fall of 1887 as part of the College of Agriculture at Lake City. Bulletin No. 2, published the following year, contained an entomological section by Wm. H. Ashmead. He discussed the life histories and habits and suggested controls for several common pests, including the corn leaf aphid. He reported that a mixture of white hellebore and flour killed many of the aphids but was not considered satisfactory.

The First Annual Report of the Experiment Station, published in 1889, contained an Entomologist's Report by Jas. C. Neal, M.D. Dr. Neal gave several formulas for control of the peach tree borer and the plum curculio. Most of these contained Paris green or other forms of arsenic in combination with various other materials. Perhaps the fact that he was a physician had some influence, but it is interesting to note that even then, some consideration was given to possible danger from insecticide residues. Neal wrote, "It is hardly necessary to remark that these are powerful poisons, and stock should be kept out of orchards after their use; though applied once to fruit, at setting, there will not be a trace of it at maturity."

Bulletin No. 9, written in 1890 by Dr. Neal, has the title "Entomological Notes." The first paragraph is most interesting because it indicates that farmers in those early days apparently did not take experiment station recommendations too seriously, but especially because it tells us that the good Doctor was a prophet with considerable wisdom and foresight. He wrote "It is very common to ridicule the efforts of practical entomologists, and belittle the results obtained by their methods of preventing or mitigating the ravages of insects, but the fact remains that at no distant date no farming will be a success without considerable knowledge of the habits of insect foes and the means devised to oppose them." How right he was!

This same Bulletin 9 is interesting though somewhat disillusioning, in another respect. Most of us have heard stories by some "Old Timer," how in the "Good Old Days" one could plant a crop that practically grew itself and was never bothered by diseases, insect pests or other troubles. Statements by Dr. Neal indicate that farming was not always such a carefree occupation, at least not for all farmers. Referring to insect losses, he wrote, "at the lowest calculation, the average loss of crops to the farmers of Florida is not less than 20 per cent, and often half or all of some staples." He further estimated that insects in the field and in the crib destroyed at least 25 percent of the Florida corn crop.

Seventy years ago tobacco was an important crop in Florida, as it is today. A bulletin published in 1891 contained a section on tobacco which included information on insect pests of the crop. A mixture of Paris green with meal or flour applied with a perforated can or pepper box was recom-

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mended for cutworm control. Hand picking was advised to protect the plants from hornworms and budworms. It was also stated that hornworm moths could be poisoned by putting a mixture of cobalt and honey in "Jamestown (gympson) weed blossoms" and place them in the tobacco field at night. This method likely killed some moths and it may have been about as good as some of the light traps sold today. These also catch moths but do not prevent egg laying in the tobacco fields.

A good proportion of the bulletins published by the Experiment Station, while it remained in Lake City, contained information on insects of field crops. The pests most frequently mentioned included the fall armyworm on various grasses, leafhoppers in pastures, grasshoppers on oats, corn, cowpeas, and other crops, as well as the various pests of tobacco. A. L. Quaintance, in Bulletin 40, gave a thorough discussion of the fall armyworm and recommended some control measures prefaced by this statement: "The value of the hay crop is sufficient to make it profitable to take steps to check the ravages of this insect." He recommended spraying the meadow with 1 pound of Paris green in 150 to 200 gallons of water. He also was cognizant of potential hazards from residues for he stated "One or two good rains after spraying, would be sufficient to wash the poison from the grass, and it could safely be cut for hay."

P. H. Rolfs, who later became Director of the Experiment Station, gives us a good idea of the insecticides available at the turn of the century in a bulletin entitled "Insecticides and Fungicides." He discussed the merits, shortcomings, and methods of application of Paris green, London purple, kerosene emulsion, resin washes, sulfur (in various forms), pyrethrum, tobacco decoctions and combinations of insecticides and fungicides.

During December 1906 and the first few months of 1907 the Florida Agricultural Experiment Station moved to Gainesville and became a part of the newly formed University of Florida. Investigations of agricultural pests, including insects of field crops, have continued without interruption. As the Experiment Station grew and expanded, branch stations and field laboratories were established in various areas of the state. Work with pests of field crops and pastures is carried on at the North Florida Station at Quincy, the Everglades Station at Belle Glade, the Gulf Coast Station at Bradenton, and the Range Cattle Station at Ona.

During the past half century there has been a continuous, and at times rapid expansion of agriculture in Florida. With increasing acreages under cultivation and concentrations of crops in certain areas, insect pests became more troublesome and there was a corresponding increase in demand for information on pest control. Entomological research was directed where the need seemed greatest and in all the annual reports and many bulletins one finds information on the control of insect pests of peanuts, field corn, velvet beans, tobacco, sugar cane, and pastures. A paragraph from the introduction of the 1922 Annual Report gives a graphic picture of the insect situation at that time and it shows that progress was being made in pest control. It states in part, "Insects, like plant diseases, take annual tolls of many thousands of dollars from Florida farmers. Damage to individual crops frequently ranges from 25 to 100 percent. The work of the Station's entomologists in the past has resulted in satisfactory control measures for many of the common citrus insects, and in successful methods of avoiding damage to sweet potatoes, field crops, velvet beans and subtropical fruits."

New insecticides were tested as they became available and from time to

time a new material was recommended to farmers for use on their crops. Lead arsenate paste was recommended for the control of the velvet bean caterpillar in 1914 and two years later powdered lead arsenate replaced the paste form. In 1922 calcium arsenate was recommended for control of the cotton boll weevil. About 1930, natural and synthetic cryolite and barium fluosilicate became available and these were used to some extent on Florida crops.

Now let us see what insecticides were available in 1940, the first year of the 20-year period with which we are presently concerned. At that time the insecticides used on field crops were classified as stomach poisons and contact poisons. The principal stomach poisons were compounds of arsenic and fluorine. Lead arsenate and calcium arsenate were the only arsenicals used extensively on general farm crops. Magnesium arsenate and Paris green were used to a limited extent on field crops and the latter was used in grasshopper and cutworm baits. Of the fluorine compounds only natural and synthetic cryolite were commonly used.

Contact insecticides were used against sucking insects, such as aphids, leafhoppers, thrips, scales, whiteflies, and plant bugs. The contact insecticides included sulfur in various forms, oil emulsions, nicotine preparations, pyrethrum, rotenone, and sabadilla. These insecticides were especially useful against pests of citrus, other fruits, and pecans. They were used less extensively on vegetables and to a very limited extent on field crops.

Something happened in the early nineteen-forties that gave us a new concept of pest control. We refer of course to the discovery of the insecticidal qualities of the compound DDT and the development of this insecticide and related chlorinated hydrocarbon materials. DDT was first produced in Switzerland and in 1941 it quickly controlled a severe outbreak of Colorado potato beetle which threatened the Swiss potato crop. DDT was first introduced into the United States near the end of 1942 and it was tested first at the U.S.D.A. laboratory in Orlando. Apparently the first experiments with DDT as a control for pests of cultivated crops in Florida were made by J. C. Russell at the Celery Investigations Laboratory at Sanford. In 1943 Russell reported results of a corn earworm control experiment using DDT sprays and dusts. He found the dust better than the spray and reported that some plots produced 95 percent worm-free ears. Earworm control had been laborious, expensive, and not too effective, and such good control with a few dust applications seemed almost unbelievable. Later, experiments and commercial use proved the value of DDT and sweet corn production in Florida jumped from 6,000 acres in 1947 to 40,000 acres in 1957. Thanks to DDT, Florida sweet corn now goes to market virtually free from earworm damage.

After its introduction DDT was tested by entomologists against most of the pests of cultivated crops and by 1945 it was used extensively by Florida growers to control many of the vegetable pests as well as the velvet bean caterpillar in peanut fields and armyworms in pastures.

The fact that DDT controlled such a wide variety of insect pests and that it had a long time residual activity amazed farmers and entomologists alike. As stories of its effectiveness appeared in newspapers, magazines, and other news media, people were led to believe that our insect problems were ended, and some boldly stated that soon there would be no need for entomologists. However, there are no authenticated records than any good entomologist suffered from insomnia because of fear that DDT would leave him with nothing to do. Without question DDT was better than

any previously used insecticide and by its use pests could be controlled much better than before. Still, DDT was not the perfect insecticide that everyone hoped for and its shortcomings and faults soon became apparent.

DDT was only the first in the long array of synthetic organic insecticides now available for pest control. New products were tested as they appeared and they were quickly accepted and used in Florida agriculture. In fact entomologists were hard pressed to test and evaluate new products by the time farmers were using them on their crops. In February 1949 a Handbook on "Pesticides and Their Uses in Florida Agriculture" was issued by the Florida Agricultural Experiment Stations, Florida Agricultural Extension Service, and a Florida Industries Committee. The foreword in this handbook states "The information within these covers was compiled to clarify, if possible, the complex situation resulting from continuous introductions of many new pesticides." Older materials were not listed because their use was generally understood and since, in many instances, the new materials had proved superior. The handbook shows that DDT was used against general truck crop insects except aphids, mealybugs and spider mites. TDE (DDD) and methoxychlor were used against the same pests as DDT. They were considerably less toxic than DDT to warm-blooded animals, but in many cases they were less effective against insects. Toxaphene was used against some vegetable pests and it was especially effective against cotton insects, stink bugs, several kinds of caterpillars and other pests of field crops. Chlordane was particularly useful in the control of grasshoppers, ants, mole-crickets and stink-bugs. Benzene hexachloride (BHC) was effective against about the same pests as chlordane. BHC was not recommended for use on root or tuber crops because it imparted an objectionable flavor to the product. Three organic phosphate insecticides were available in 1949. TEPP and HETP were used against aphids, thrips and spider mites. Parathion, which had been a life saver for tobacco growers in 1947, when the green peach aphid seriously threatened their crop, was used against aphids on other crops and it also gave excellent control of scale insects and several kinds of lepidopterous larvae.

The rapidity with which new materials were introduced showed quite clearly that DDT and the insecticides that followed it were not cure-alls for every insect problem. Chemists, insecticide manufacturers and entomologists have all been busy trying to develop still better materials. During the past 20 years more than 100,000 organic chemicals have been tested for potential insecticidal properties and more than 100 are in commercial use. At least 30 insecticides and miticides are now used extensively in Florida agriculture. Some are used almost exclusively on vegetables, ornamentals or fruit crops and these have little application to general field crops. There is no need to describe a long list of insecticides and it will suffice to name only a few of those generally used on field crops and to mention some of the common pests that they control. DDT, chlordane, toxaphene, TDE, and parathion were available ten years ago and they still are used extensively. Other materials introduced in later years and now used in field pest control include aldrin, dieldrin, endrin, heptachlor, sevin, malathion and demeton. Aldrin is especially useful in grasshopper control and it has been effective against wireworms and certain other soil insect pests. Dieldrin is a persistent insecticide like DDT and it is used against white-fringed beetles, fire ants, wireworms, and other pests where long residual action is wanted. Endrin is one of the principal insecti-

cides used against hornworms and budworms on tobacco and it is fairly effective in holding down aphids, stink bugs, and grasshoppers. Endrin also gives good control of the cotton boll weevil and the boll worm. Heptachlor is a good insecticide to control spittlebugs in pastures and it also is used against grasshoppers and as a soil treatment for wireworms. It is one of the insecticides chosen for use in the imported fire ant eradication campaign. Sevin, one of the newest insecticides just coming into commercial use, differs chemically from both the chlorinated hydrocarbons and the phosphatics and it is less toxic to warm-blooded animals than most of those materials. Tests have demonstrated the effectiveness of Sevin against a variety of insects and it seems safe to predict that it will eventually be recommended for the control of many pests of tobacco and other field crops.

At least a dozen new phosphatic insecticides have been introduced during the past ten years. They are used principally on fruits, vegetables, and ornamental plants, but some are also useful in field crop pest control. Malathion is used to control aphids, leafhoppers, and some caterpillars. It it much less poisonous than parathion to warm-blooded animals and thus can be used in many situations where parathion is not recommended. Malathion is of special interest to Floridians because it was the insecticide used in the bait sprays applied to more than six million acres of Florida land during the successful Mediterranean fruit fly eradication campaign in 1956-57. Demeton, a systemic insecticide, and trithion, another phosphatic, are used to control aphids on pasture grasses and spider mites on clovers.

Someone may ask, can we really control pests on field crops better today than we could twenty years ago. The answer definitely is yes, but it may need some explanation. Farmers and others now expect much more from insecticides than they did a generation ago and controls which now are considered only average, or even poor, would have been quite acceptable then. It also is true that pest control has become more complex and complicated since the advent of the modern insecticides. Though a given material may kill many kinds of insects, it usually is outstandingly effective against one, or a few kinds of pests, and inferior to other materials in the control of other pests. Obviously it is quite necessary that the pest be correctly identified before control recommendations can be given and the insecticide applied. Often the farmer is unable to identify the pests on his crops and this places more responsibility on county agents, entomologists, and other agricultural workers who are called upon for control recommendations. Today's insecticides are superior to those of twenty years ago but to derive their full potential it is essential that the proper materials be chosen for the jobs at hand.

There now are reasonably satisfactory controls for most pests of field crops but what about the future? We are told that in a comparatively few years our stores of surplus foods and feeds will be gone and there will be a need for greater production of agricultural crops. New lands will be cleared for cultivation and more intensive cultural practices will be used on field crops. Insects and mites will still be a problem and the need for effective pest control will be greater than now. Improved insecticides probably will be available to the farmer and he will be better informed on their use. A great deal more will be known about the pests themselves and their relationships to the crops they attack. Greater use will be made of parasites, diseases, and other natural control factors. The use of hor-

mones in pest control is being explored now and no one can forsee what part radiation research may play in future insect control practices. The conflict between Man and insects has gone on for thousands of years and it likely will continue as long as both live together on earth. Man has held his own thus far and we have confidence that he will continue to do so.

A Review Of The Research On The Diseases Of Agronomic Crops And Their Control In Florida 1939-1959[1]

PHARES DECKER[2]

In 1938 the Florida Agricultural Experiment Station celebrated its 50th Anniversary. It was evident from the many published articles that the growers had received many benefits from research done by the station workers. However, there was only limited information as to the control of agronomic plant diseases. Among the 14 plant pathologists employed on the station research staff only one was engaged full-time in the study of diseases of agronomic crops. The growing of cigar-wrapper tobacco had become concentrated in a limited area, which justified the services of a plant pathologist. More acres were devoted to the growing of corn than to any other agronomic crop. The diplodia disease of corn had received some attention by the plant pathologist.

A few reasons why this situation existed and why changes have been made during the past 20 years might be of value.

We live in Florida as guests of plants. We are completely dependent upon plants because they feed the populations of the world and produce much of the shelter and luxuries we enjoy. Only plants among living organisms are capable of using solar energy to produce organic compounds that are essential for animal metabolism and growth. The health of these plants is vital to society and human progress. Diseases of plants may affect large groups or communities of people. The disease of an individual plant may be relatively unimportant. However, when large numbers of plants become diseased, the food supply of an entire country may be affected. The health of plants has interested man since the dawn of civilization. Plants were subject to diseases long before they were brought under cultivation, but the diseases were of little interest to man until he began to give special care to those plants that furnished him food, clothing and shelter.

The greatest need for plant disease control is found when crops are artifically cultivated. The development of agriculture usually intensifies the plants in a given area which makes any disease more acute. Several hundred people living in a single square mile area create a serious public health program. When several million plants of like constitution are grown on one acre, the disease from one plant may easily spread to another. The plant pathologist knows that this crowding of plants offers optimum conditions for the development of epidemics.

[1]Florida Agricultural Experiment Station Journal Series, No. 1037.
[2]Plant Pathologist, and Head of Department.

In modern agriculture, the crowding of plants is deliberate. This crowding of plants is designed to promote maximum agricultural production. Thus, every successful effort by the plant breeder, the agronomist, the soil scientist to improve yields by adding to the carrying capacity of the soil, intensifies the disease problems. A great increase in agricultural production had been made in Florida before 1939 which increased the needs for a society to give aid and direction to the solution of agricultural disease problems.

Disease control measures, whether successful or not, increase the total cost of production. Disease control can be justified only if the unit cost of production is lowered or the quality increased. In a review of the research on the control of diseases of agronomic crops before 1939, we find one plant pathologist assigned to full-time research on the diseases of cigar-wrapper tobacco located at Quincy, Florida. Thirteen plant pathologist were assigned to various vegetables, ornamentals and fruit crops. The intensive cultivation of these crop plants as grown in Florida increased the disease problems.

Acknowledging that disease problems existed, the Agronomy Department under Hatch Project No. 55 reported that during the winter and spring almost all of the plants of *Lupinus angustifolius* were killed by diseases, of which rhizoctonia, botrytis and rootknot were the most common. There was a project "oat variety testing" in which resistance to crown rust was considered essential for all adapted varieties. Selections were being made for adapted, improved varieties of peanuts, corn, oats, millet, pasture grasses, sugar cane and clover. Thus the disease problem of most agronomic crops was a part of the over-all program of introducing, selecting or breeding disease resistance, or disease tolerant crop plants. This was often accomplished with little knowledge of the organism causing the plant disease.

The types of distribution of microorganisms in Florida soil were studied under State Project 326. This research was designed to learn more of the role microorganisms played in crop production with the idea of improving the conditions for better plant growth. A number of projects dealing with variety testing, crop rotation, clean cultivation, amount and types of organic matter, water requirements and soil fertility had as a part of this objective the reduction and control of plant diseases.

In 1939 the production of cotton, formerly a sizable acreage in Florida, was on the decline. Considerable investigations were being conducted on Sea Island cotton which included the control of insects and disease pests. Dr. R. R. Kincaid had continued and expanded the research on cigar-wrapper tobacco started by Dr. W. B. Tisdale. The cigar-wrapper industry, threatened by a serious disease known as blackshank, had been saved by the development of resistant varieties. The intensiveness of tobacco cultivation offered little opportunity for long time rotation. This, as expected, resulted in the occurrence of a number of serious diseases. While the resistance to blackshank in tobacco is maintained, attempts to add resistance to mosaic, blue mold, Fusarium and bacterial wilt and nematodes have been included in the research program by the pathologist. The control of blue mold, primarily a seedling disease found in the seed bed, was satisfactorily attained by the proper use of PDB (Paradichlorobenzene). Flowers of sulfur was being recommended and used on peanuts for the control of cercospora leaf spot, but with doubtful monetary success. Stalk and ear rots of field corn, incited by species of diplodia, were being studied

in 1939 by Dr. R. K. Voorhees who had replaced Dr. A. H. Eddins. This project was dropped as potatoes and citrus became more intensively grown and incurred heavier disease losses than the corn crops. In 1940, under Adams Project 269, E. West was studying the host relations and factors influencing the growth and parasitism of *Sclerotium Rolfsii*. This organism, commonly called Southern blight, has an extremely wide host range and control studies were largely confined to the intensively grown vegetable crops. This organism which is soil-borne, living on plant debris and organic matter in the soil, has not been economically controlled with agricultural chemicals. Dr. W. B. Tisdale and Dr. L. O. Gratz, under Adams Project 281, were studying the cause of failure of seed and seedlings in various Florida soils. Largely confined to vegetable crops, the chemical seed treatments were occasionally applied to seeds of agronomic crops.

The research and application of disease control principles on agronomic crops have increased in scope and personnel in recent years as the cattle and hog industry has demanded improved grazing crops and concentrated feeds.

LUPINE INVESTIGATIONS

Lupines, introduced as a winter legume cover crop in 1939, appeared to be well adapted to a wide range of soil types and to have few serious plant diseases as grown in Florida. A severe reduction in seed germination during summer storage was discovered by the writer in 1943 which prompted a research project on the control of seed-borne and seedling diseases of lupines. The scope of these studies were later enlarged to include all diseases of lupine. As this crop became more extensively and intensively grown in Florida, many new diseases were found, some of which seriously affected the crops. In cooperation with the agronomist, the lupine program was expanded to cover breeding for resistance to disease and insect pests, rotation, time of planting, fertilization and proper curing and storage requirements for the lupine seed. Alta blue, an alkaloid strain of *angustifolius*, was developed which was resistant to anthracnose and adapted to growing conditions in northwest Florida.

Although sweet (non-alkaloid) strains of blue lupine were selected and grown with some success, the sweet strains of yellow lupine (*L. luteus*) appeared to be more stable and to offer more promise as to combination winter grazing and cover crop. In 1947, a disease condition was observed in field grown lupine plants which proved to be a seed-borne virus. Dr. M. K. Corbett has identified this virus as a strain of bean yellow mosaic virus. Although sudden cold weather with heavy frosts often reduced seedling stands, the virus was largely responsible for the decline of lupine acreage. On July 1, 1957, Dr. S. A. Ostazeski, plant pathologist with the U. S. Department of Agriculture, was assigned to Gainesville to do research on the cause and control of legume disease. He is continuing the research work on lupines, in cooperation with other workers at the Agricultural Experiment Station, in breeding and chemical disease control. He is also investigating the diseases of summer legumes including crotolaria and big trefoil.

THE SMALL GRAIN IMPROVEMENT PROGRAM

The use of small grain crops, oats, rye, wheat and barley, which predates the founding of our society, has been greatly increased in recent years. They are grown both as winter forage and seed crops. Losses from

disease have increased as these crops were increased to meet the demands of the growing cattle industry. Both crown and leaf rusts of oats must be controlled for the crops to be grown successfully. These diseases have never been controlled successfully by the use of chemical fungicides, but the plant breeders, through continuous effort, have been able to keep the diseases in check through the development of disease resistant varieties. The U. S. Department of Agriculture Research Service, through their extensive program in developing improved varieties of oats for the United States, made available to our plant breeders and pathologists a vast amount of breeding material that has been used in Florida. In 1951, Dr. R. W. Earhart, plant pathologist with the U. S. Department of Agriculture, was assigned to the Main Station to cooperate in the small grain improvement program. Just as the plant breeder can develop new varieties of small grains, certain disease producing organisms also produce new strains of the organism, which may incite disease on each new variety. Thus, the breeding for resistance to rusts in small grains is a continuous effort. It has been estimated from recent observations that the life expectancy of a rust resistant variety of oats in Florida may be from 3 to 5 years.

Oat diseases caused by Helminthosporium species were of minor importance in Florida until the advent of a new strain, *H. victoriae*. This new strain threatened to eliminate the high yielding, rust and smut resistant varieties that had been obtained from crosses with the Victoria variety of oats. It is primarily a seedling and culm disease, but will reduce the seed crop and forage yield. Seed treatments with organic mercury compounds offered only partial control, so it remained for the breeder to produce resistant varieties. All varieties of oats recommended for Florida at the present time are susceptible to new crown rust races 264 and 290. Resistance to race 264 has been found in lines of irradiated Floriland oats. Plant disease resistance from the use of irradiation represents a new tool in the breeding for disease resistance in plants.

Florida black rye for early grazing and abruzzi rye for later grazing have been recommended for Florida, although both are susceptible to disease. Gator rye developed at the Experiment Station offers more disease resistance and certain desirable agronomic characteristics over these former varieties. Released in 1956 it carries resistance to leaf rust, stem rust, and powdery mildew, but is susceptible to leaf blight. Dr. H. H. Luke, plant pathologist stationed at Gainesville, recommends seed treatment using ceresan M or ceresan 100 for the control of this disease.

Wheat and barley, grown on a limited acreage are included in Dr. Luke's program. The testing of many varieties for their reaction to rust, mildew and other diseases constitutes the major part of the investigations for disease control.

PEANUTS

Prevention of disease, rather than cure, is the best rule for control of the diseases of peanuts. Although the use of fungicides as seed treatments or as dusts or sprays on growing plants are recommended as preventive measures, additional control measures are needed. These are management practices; crop rotation, planting on light-textured, well-drained soils and a minimum of mechanical damage in cultivation.

Estimates of crop losses in peanuts due to diseases are very high. Southern blight, *Sclerotium Rolfsii*, alone causes losses annually from 10

to 20 million dollars while concealed damage to the nut, leaf spots and rust may add another 5 million dollars. While the plant pathologists in Florida have done limited amounts of work on peanuts, pathologists in neighboring states have had extensive programs on disease control of this crop. Perhaps with no other agronomic crop has so much investigation resulted in so few, definite successful recommendations as to the use of chemicals for disease control. The development of high yielding varieties, with small amount of concealed damage and resistance or tolerance to diseases, involves the present program. Material increases in yields have been reported in Georgia by using recommended crop rotation, deep plowing to cover all organic matter, shallow planting of seed and non-dirting cultivation. The use of weed killers to eliminate the need for cultivation is a recent recommendation which appears to have promise.

CORN

There are many diseases found on field corn. These can be separated into the following groups: diseases infecting seedlings, stalk rots, leaf blight, rusts and smuts, and ear or grain rots. Since the work of A. H. Eddins and R. K. Voorhees at the Main Station, no research project on diseases of corn has been conducted by plant pathologists.

Only the seedling diseases of corn are successfully controlled by chemical fungicides. The mercury containing compounds are effective, but are poisonous to animals. In recent years these have been largely replaced by organic non-mercurials, such as Arasan, thiram, phygon and captan. In the hybrid corn breeding program being conducted by various experiment station and private companies only varieties resistant or tolerant to stalk rots, rusts and smuts are considered of any value. The leaf blight caused by Helminthosporium spp. has become increasingly severe in recent years. Fungicides are recommended for the control of this disease on sweet corn, but have not proved of economic value on field corn.

Clean cultivation, crop rotation and proper soil moisture with recommended rates and type of fertilizers are widely used. Adapted varieties for a given area have been developed.

TOBACCO DISEASES

Among agronomic crops, tobacco has been most intensively grown. In the early years tobacco diseases were kept under control by planting on new land each year. Today with acre allotments and with the shade tobacco located in limited areas this is not practical. Plant pathologists have been employed to devise economic control methods. Blue mold, a common disease in the seed bed, is satisfactorily controlled by spraying or dusting with fermate, zineb or maneb replacing PDB used 20 years ago. The blackshank resistance developed by W. B. Tisdale for the cigar-wrapper tobacco has been maintained at the Quincy Station. Improvement in varieties, for better burning qualities, resistance to nematodes and foliage diseases is being conducted by Dr. R. R. Kincaid.

Blackshank appears in the fields of flue cured tobacco and has caused serious losses in the Carolinas, Kentucky and Virginia. Although this disease has been reported from Florida and Georgia, for reasons not fully known to the plant pathologists, it has never caused serious losses. The

breeding programs have been only partially successful in developing adapted, resistant varieties. Thus the recommended control measures, where blackshank causes economic losses, include crop rotation, water control and use of disease free plants.

Nematode pests of tobacco have been recognized as causing severe losses. Plant breeders are making progress toward an adapted resistant variety, but crop rotation and soil fumigation are recommended. Ethylene dibromide and D-D mixture applied in the pre-plant row have increased yields. They should be used as recommended, especially the D-D mixture, because too much of the chemical may increase the chlorine content of the leaves.

LEGUMES OTHER THAN LUPINES

The annual legumes grown in Florida are classified in two groups, winter and summer, according to their adaptation. They are grown in rotation, for green manure, for forage and hay. The winter annuals are field pea, vetch clover, roughpea and bur clover. Summer legumes include lespedeza, cowpea, velvetbean, soybean, crotolaria, Kudsu and Alyce clover. Lespedeza, sweet-clover and big trefoil are perennials that have been grown.

None of these plants is native to Florida and all are susceptible to diseases, some of which are widespread and serious. The field-pea, Austrian winter, seriously affected by leaf and stem blight, septoria leaf spot, powdery mildew and root rots, lost favor with the growers soon after lupines were introduced in the early 1940's. The vetches, grown mainly as a cover crop, were susceptible to anthracnose, blight and root rots and were replaced with lupines. Crimson clover, restricted in acreage by soil and moisture requirements, was attacked by sclerotinia and sooty blotch. Only a very limited amount of research has been done on any of the diseases of these legumes.

Among the summer legumes, lespedeza has been grown successfully in spite of Southern blight, powdery mildew and nematodes, which reduce stands and total yields. The diseases of velvet beans, cowpea and crotolaria have received limited attention. Selections have been made for improved disease and nematode resistant lines.

Soybean, grown as a seed and oil crop, has increased in acreage with the development of high yielding, disease and nematode resistance. Jackson, the variety recommended for north Florida, has been out-yielded by several selections now under test at several locations in Florida. If soybean is to be grown successfully in Florida, a number of diseases must be controlled by breeding or the use of agricultural chemicals.

PASTURE AND TURF GRASSES

Florida has long been known for its year round grasses for cattle grazing. The rapidly expanding cattle industry has demanded improved pasture grasses which are adapted to variations in soil, moisture and fertility requirements. This has greatly increased the breeding and testing of introduced and native materials to meet these needs. The agronomist has been primarily responsible for these improvements with only a limited amount of aid from the plant pathologist. The breeding and selecting program

designed to develop or introduce improved grasses has been concerned with eliminating the disease susceptible lines in the testing program. The improved varieties of grasses, Coastal and Suwannee bermudagrass, Pensacola bahiagrass and pangolagrass, all have diseases. However there are no recommended chemical controls.

In 1955, Dr. T. E. Freeman was employed to investigate the disease of turf grasses and to develop disease control measures. He has identified several new disease producing organisms and has worked out the life history of other pathogenic organisms. Brown patch, caused by rhizoctonia, attacks St. Augustine, bahia, rye, Bermuda, zoysia and centipede grasses. The disease is controlled by spraying with thiram, Kromad or mercury chlorides. There are strains of the Sclerotinia fungus, the cause of Dollar spot, which will cause damage in Florida at higher temperatures than strains of the same organism found in Ohio and Rhode Island. This disease can be controlled on St. Augustine, Bermuda, zoysia, bahia and centipede grasses by the use of cadmium compound. Grayleaf spot of St. Augustinegrass, caused by *Piricularia grisea*, is controlled by the use of thiram, Kromad or captan. A newleaf-spotting disease of St. Augustinegrass, caused by cercorpora, has been described. Control measures have been determined for rust on rye, bermuda and St. Augustine grasses and for Helminthosporium leaf spot of bermuda, zoysia and St. Augustine. These disease control measures can be applied to grasses on home lawns, parks and and golf courses because of the relative value of these grasses as compared with the value of pasture grasses. The knowledge of the action of the chemicals on the disease producing organisms may allow the research worker to develop control measures for diseases of pasture grasses.

In addition to the plant diseases already listed we should add anthracnose, common on many grasses, ergot of many grasses, especially Paspalum, smut of Agropyron, Bromus, Elymus and Hordum species. Very little is known about the control of viruses of grasses although a number have been described. As these plants are grown more intensively it is reasonable to expect the diseases to become more important and severe.

CASTORBEANS AND SESAME

In 1954, in cooperation with the U. S. Department of Agriculture a research project under the direction of Dr. A. A. Cook was initiated to investigate the diseases and agronomic adaptation of castorbeans and sesame. This is a regional project to test the disease reaction of the breeding lines from other areas and to evaluate the possibilities of developing a new agricultural cash crop for Florida. Dr. R. G. Orellana has continued and expanded these investigations since 1957. While little progress has been made toward the development of a castorbean adapted to Florida, valuable information on the reaction of selected lines to a number of diseases has been made available to plant breeders in Texas and Oklahoma. Selected lines of sesame show some promise as grown in northern Florida.

SUMMARY

In 1939 when our society was established, one plant pathologist was devoting full-time to the control of diseases of cigar-wrapper tobacco. Another plant pathologist was studying the disease of field corn caused by

diplodia as a part of his research program. Today there are five plant pathologist engaged in the study of the cause and control of diseases of agronomic crops.

As a given crop is grown more intensively, the disease problems become more important. The increasing production of many agronomic crops to the needs of the expanding agricultural industries in Florida will increase the disease problems. The help of the plant pathologist will be needed to aid the agronomist, the soil scientist, the entomologist and the nematologist to provide the plants that will thrive in Florida.

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Early Experiences with Hydroponics at The Public Health Research Laboratories

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INTRODUCTION

The soilless culture of higher plants, first developed some 100 years ago as a laboratory tool, is still important in research today.

The hydroponic units of the Public Health Research Laboratories in Stuart are among those in this country that have been established for experimentation. The primary and original purpose has been to determine by what means and how successfully vegetable crops can be grown without the use of residual chemical pesticides.

To carry out the objective, gravel culture was chosen because it assures a semi-sterile root medium which minimizes the possibilities of insect and disease infestations that occur in or through the soil. Of course, as Hoagland and Arnon (1) emphasize, plants grown in water culture are not thereby protected against all or even most diseases, nor are the attacks of every insect thwarted. In fact, some authors (2, 3, 4) stress that regular and systematic spraying with insecticides and fungicides is as essential to crop production in hydroponics as it is in field culture. This is particularly the case in southern Florida. Other precautions must be taken, therefore, if the crop is to be protected by means other than foliar pesticides. Accordingly, through trial and error experimentation, efforts were made to grow vegetables without the use of pesticides. This paper concerns trials along this line.

Studies on sanitation, nutrition and composition of crops treated and untreated with pesticides, figure among the secondary purposes of this research, as does investigation of the influence on the plants of the very special environmental factors in the hydroponic culture. In addition to establishing the conditions of environment which allow for the production of pesticide-free edible crops (for those who can afford the cost of their production), the accomplishment of these purposes can lay the foundation for further comparative experimentation with applied pesticides, their breakdown products and their metabolic effects.

EXPERIMENTAL

The first two hydroponic units, which were built along conventional lines, began operations in the spring of 1957. Each unit consisted of six concrete beds filled with river-bottom gravel, and three underground storage tanks. Sump-pump feeding and drainage by gravity were provided. The pumps were activated by a time-clock mechanism. The units were completely enclosed by screen on the sides and on the level top in order to keep insects away from the plants.

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Emphasis was placed on good sanitation. Before operations began, the tanks, beds and gravel were treated with a solution of calcium hypochlorite containing 1000 ppm chlorine. Seedlings were fumigated with methyl bromide to prevent importing insects into the culture beds and enclosures. When planted directly into the gravel, commercially treated seeds were used.

1957-1958 CROPS

The results obtained in 1957 were by no means entirely satisfactory, but were encouraging. Growth and production of most species were sufficient, even very good in some cases (See Table 1). Eggplants, corn, head lettuce, peppers and squash failed, either because of unfavorable temperature, diseases, or some unknown reason.

Eggplants grown from June to September flowered, but produced no fruit probably because the average day and night temperatures in this period were higher than the optimal of 20° C by day and 14° C at night (5). The corn had an elongated appearance, weak stems, and abnormally small cobs. Poor pollination and mineral nutrient deficiencies might have played a part in the failure, as well as insufficient depth of the gravel medium (about 7") for developing a good root system. The real reason for poor heading of lettuce (Iceberg, Big Boston) is not clear. This could be due to hot weather (which is a known cause) when planted in late spring, but could not be the only reason since the same symptoms appeared in lettuce grown in the cool months.

DISEASES

The pepper plants (California Wonder) were badly damaged by the so-called "Mosaic Complex," a malady presumably viral in nature. As a consequence, some peppers were deformed and abnormally small. It was peculiar that on different occasions the same plants at the same time were bearing both normal and badly deformed fruit. To minimize the possibility of such infections in the future, the pepper seedlings are now transplanted into the hydroponics from seed beds on the premise, rather than purchased from commercial suppliers.

Some of the squash plants soon became infested with powdery mildew which spread quickly to all the other squash regardless of their growth stage. This vegetable was discontinued. Cucumber plants (Burpee Hybrid) grown nearby at the same time as the squash were free of mildew.

Apart from the peppers and squash, the other plants were not affected by diseases. When the number of species and plant individuals is considered, the proportion of healthy to diseased plants was very favorable. This is important in the continuing experiments.

INSECTS

After a short insect-free period, aphids and leaf miners attacked a great number of the plants grown in 1957. In this situation, it proved absolutely necessary to make an exception to the original idea of not using pesticides of any kind. In the face of an enormous multiplication of aphids, we modified our approach and decided to use an insecticide.

TABLE 1.—PLANTS GROWN IN THE HYDROPONICS FROM MAY 1957 TO SEPTEMBER 1958

Species	Commercial names of the Varieties	Crop Yield
BEAN (STRING) (*Phaseolus vulgaris L.*)	Kentucky Wonder	Good
BEAN (LIMA) (*Phaseolus lunatus L.*)	Fordhook 242	Fair
BROCCOLI (*Brassica oleracea var. botrytis L.*)	Greenbud	Good
CABBAGE (*Brassica oleracea var. capitata L.*)	Copenhagen Market	Fair
CELERY (*Apium graveolens L.*)	Fordhook	Excellent
CORN (SWEET) (*Zea mays L. var. saccharata (Sturt) Bailey*)	Golden Beauty Golden Security Abbotte Cob White	Poor Poor Poor
CUCUMBER (*Cucumis sativus L.*)	Burpee Hybrid	Excellent
EGGPLANT (*Solanum Melongena L.*)	Florida Highbush Black Beauty	Poor Poor
ENDIVE (*Cichorium endivia L.*)	Broad Leaved Batavian	Good
KOHLRABI (*Brassica caulorapa Pasq.*)	Early White Vienna Early Purple Vienna	Fair Fair
LETTUCE (*Lactuca sativa L.*)	Salad Bowl Iceberg	Good Poor
OKRA (*Hibiscus esculentus L.*)	Clemson Spineless	Good
PEPPER (*Capsicum frutescens L.*)	California Wonder	Poor
SPINACH (*Spinacia oleracea L.*)	Bloomsdale Long Standing	Good
SQUASH (SUMMER) (*Cucurbita moschata Duchesne*)	Table Queen Golden Summer	Poor Poor
STRAWBERRY (*Fragaria virginiana Duchesne*)	Unknown Florida No. 90	Fair No crop
SWISS CHARD (*Beta vulgaris cicla*)	Fordhook Giant	Excellent
TOMATO (*Lycopersicon esculentum Mill.*)	Big Boy Rutgers Manalucie Indian River	Fair Fair Good Good

Nicotine sulfate was sprayed at 0.1% regularly on broccoli, cabbage, eggplant, squash and peppers, and occasionally on other crops.

In spite of the sprayings, aphids remained a serious problem during the first year. This was not surprising because aphids, once appearing in greenhouses, are exceedingly difficult to control. Even the Earhart Plant Research Laboratory, which consists of closed greenhouses and where great stress is laid on the maintenance of sterility was plagued for two years

by periodically recurring infestations in spite of repeated parathion fumigation (5).

Leaf miners attacked the tomatoes and beans. The tiny flies could get into the enclosures even through the screen. Therefore, a commercial formulation of DDT was applied weekly to the screen, using a hand brush. No doubt this was helpful for the leaf miner invasion subsided and the plants remained relatively vigorous and productive although the problem was not solved completely.

Apart from the tomatoes and beans, the plants were almost completely free from other insects. There were found, only sporadically, some species of Thysanura, a few crickets, rhinoceros beetles, roaches, locusts and wasps on the walks or on the beds. These caused no apparent damage. Unfortunately, the degree of insect control achieved was not long-lived.

The unusually cold weather from December, 1957 through February, 1958 created a necessity for protecting the plants against damage from freezing temperatures and winds. So, during these months the hydroponic garden's screened sides and level top were covered with plastic sheeting every night, and also during daylight on the coldest days. In addition, oil and gas heaters were used at night.

This method was successful. Harvests of tomatoes, beans, broccoli, cabbage, lettuce, endive and spinach on the coldest days of that winter indicated its efficiency.

Unfortunately, repeated putting on and taking off the plastic covers caused the screen to get hundreds of holes of all sizes on the top. In spite of persistent efforts toward repairing them, there were always some holes which were overlooked and these became an easy entrance for various pests. As soon as the cold weather left, invading insects came through the holes, and from April to September, 1958 there was a steady stream of unwelcome visitors. These included leaf hoppers, horn worms, cabbage loopers and mealy bugs, all busily attacking the plants in the experimental units.

In June an even more serious trouble appeared. Some seedlings of a new tomato variety were brought from soil into the hydroponic beds. Although it was not known at the time, they were contaminated with root nematodes. Facing complete infestation, there was no choice but to remove all the plants of every species from the beds. The combination of nematodes and the insects mentioned above was too great a handicap. Therefore, the period from April to September, 1958 was lost for experimentation.

Shortly after the above dates, construction was begun on a new kind of roof. The level screened top had not been successful. Much rainfall got into the beds and sometimes overflowed the tanks. To avoid overflow and dilution of the nutrient solution by rainfall, the new roof was made from waterproof, translucent "Alsynite" (Alsynite Company of America) and was an inverted V shape. At the same time the space for hydroponic experiments under the new roof was doubled.

1958-1959

The hydroponic units I and II began operations again in November, 1958. Since that time, these two units have been used only for observations of growth and production. In the early spring of 1959 a third unit was finished, comprising 18 beds and 18 storage tanks. These beds and

tanks were smaller than those in Units I and II, and were designed in the form of two 3 x 3 (Latin) squares. Unit IV preceded Unit III chronologically, but in space (east to west) follows the latter. Operation of Unit IV began in April 1959. Unit III was completed in the fall of 1959, according to the design of Unit IV in every respect. (See Figure 1.)

The plants which were grown from November, 1958 to August, 1959 are listed in Table 2. From the standpoint of growth, two crops were disappointing. The corn was about the same as the preceding year, and head lettuce again failed to "head" properly, although leafy varieties did well.

In 1959, trials were also made with soybeans to determine if this plant is adapted to the conditions of hydroponic culture. The two varieties tested were Ogden and Bansei. The latter gave a crop of fair quality, but the grains of the Ogden were small. Soybeans will be tried again in 1960 with the addition of some other varieties better adapted to our latitude.

The new roof construction definitely improved sanitation. Insects were not a serious trouble for the whole growing season in 1958-1959. Red spider mites, however, infested the strawberry and soybean plants in April and then spread to nearby bean and pepper plants. Silica gel dust was tried on all infested plants with some apparent success except with soybean and pepper plants after they became very bushy. It was observed, but not well documented, that the dust, by its physical effect, did slow down the activity and spread of the red spider mites. But the pests, obviously a new generation, (6) appeared again in 3-4 weeks.

On the whole, the 1958-1959 growing season was satisfactory from the standpoint of disease control. Four new varieties of pepper from the Plant Introduction Station were tried in 1959. "Mosaic Complex" was distributed among these pepper plants too, but they nevertheless produced a fair crop. Mildew appeared on the cucumber plants of the Ashley variety. The rest of the plants were free from all diseases.

PROBLEMS OF THE NUTRIENT SOLUTION

Besides the problems of sanitation and protection from pests, there is another point of basic importance to the program. This is the nutrient supply itself and is related to all of the experimental objectives.

During the first year there were difficulties concerning the reaction (pH) and concentration of the nutrient solution. According to previous experience, a pH range from 5.5 to 6.5 is satisfactory for most plants. The maintenance of this fairly narrow pH range caused a great deal of work and worry, particularly in "new" concrete tanks and beds. The alkaline surface of the concrete reacted with the nutrient solution, increased the pH of the latter and the high pH caused excessive precipitation of trace elements and phosphate (2).

The normal composition of the nutrient solutions was decreased by the mineral uptake of the plants, by the high pH, and by rainfall. The nutrient element uptake by plants varies according to species, and also with the kind of nutrient solution. Under normal circumstances, the required concentration in the nutrient solution can be maintained, after analysis for different macro- and micro-elements, by additions of compounds of the elements taken up.

The most urgent task was to eliminate the detrimental effects of the pH fluctuations and the dilution of the solution caused by rainfall. A

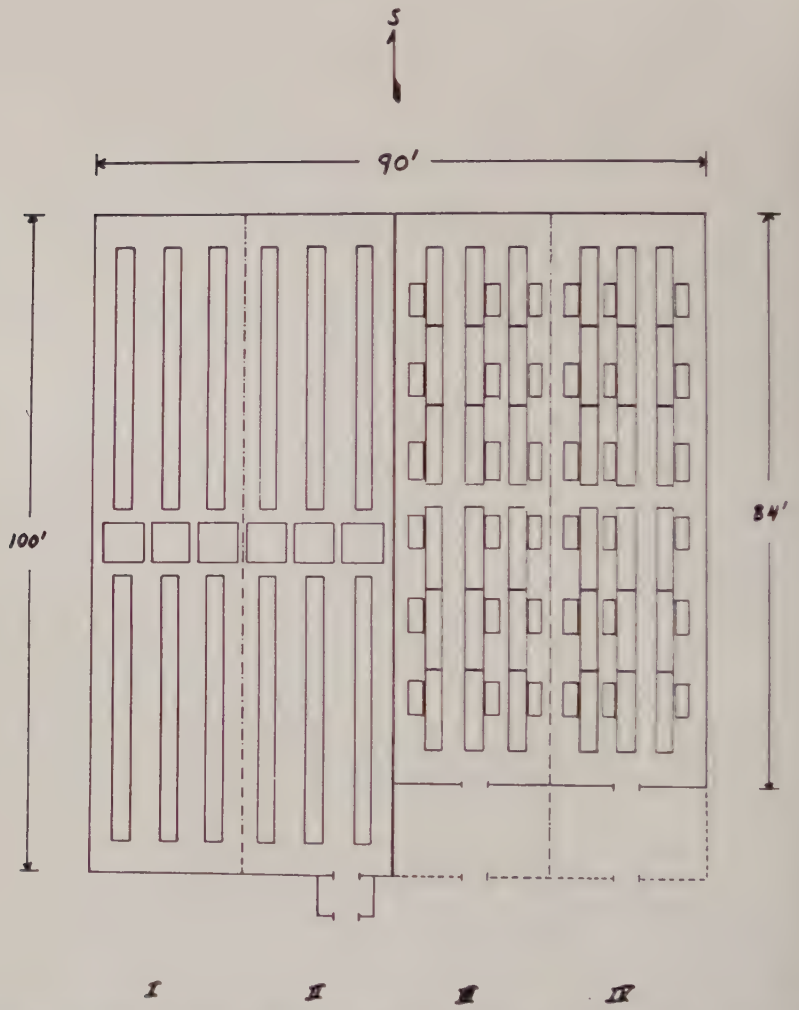

Figure 1.—Diagram of the Hydroponic Units, Public Health Research Laboratories, Stuart, Fla.

daily checking of the solutions using a Beckman pH meter, and the addition of sulfuric, nitric and phosphoric acids as frequently as was necessary, served to counteract the pH problem.

The concentration of the solution was measured with a conductivity bridge. The measurements showed generally how much the solutions in the tanks became diluted by rainfall, or concentrated by evaporation and transpiration. But this method was not serviceable for checking the mineral uptake of the plants. (See Figure 2.)

Table 3 lists data obtained in the experiments conducted in two-year-old tanks where the pH was easily controlled. In these solutions the pH was never higher than 6.2. The ratios among the individual nutrients' uptake do not agree with those claimed by Biebel (3), but the complex

TABLE 2.—PLANTS GROWN IN THE HYDROPONICS FROM NOVEMBER 1958 TO AUGUST 1959

Species	Commercial Names of the Varieties	Crop Yield
BEAN (STRING) (*Phaseolus vulgaris L.*)	Kentucky Wonder	Good
BEAN (LIMA) (*Phaseolus lunatus L.*)	Fordhook 242	Good
BROCCOLI (*Brassica oleracea var. botrytis L.*)	Greenbud	Good
CABBAGE (*Brassica oleracea var. capitata L.*)	Copenhagen Market	Good
CORN (SWEET) (*Zea mays L. var. saccharata (Sturt) Bailey*)	Golden Security Abbotte Cob White	Poor Poor
CUCUMBER (*Cucumis sativus L.*)	Burpee Hybrid	Excellent
KOHLRABI (*Brassica caulorapa Pasq.*)	Early White Vienna Early Purple Vienna	Fair Fair
LETTUCE (*Lactuca sativa L.*)	Salad Bowl Bibb Iceberg Big Boston	Good Good Poor Poor
PEPPER (*Capsicum frutescens L.*)	Plant Introductions: 131,353 (Hungarian) 167,062 (Turkish) 164,562 (Spanish) 222,133 (Peruvian)	 Fair Fair Fair Fair
SOYBEAN (*Glycine Max L.*)	Bansei Ogden	Fair Poor
STRAWBERRY (*Fragaria virginiana Duchesne*)	Florida No. 90	Fair
TOMATO (*Lycopersicon esculentum Mill.*)	Indian River Manalucie Big Boy	Good Good Good

interrelationships which exist between climatic conditions and the utilization of these nutrients should also be considered (1). Further investigations are planned in this line.

Figure 3 (a) shows the nitrate nitrogen, phosphorus and potassium levels in a given solution in one of the new tanks over a period of about three months. For the sake of comparison, Figure 3 (b) shows the changes of these elements in a solution from an "aged" tank. It may be readily seen that by analysis and additions of acids and chemicals a nutrient solution, balanced with respect to the major nutrient elements, can be maintained in "aged" concrete while this is not possible in fresh or "new" concrete. Ordinarily in hydroponic culture it is recommended that growing beds and storage tanks be coated with a non-toxic substance such as high-grade petroleum asphalt.

Hoagland and Arnon (1) and others have found that there is no single nutrient solution which by its composition would be superior to the

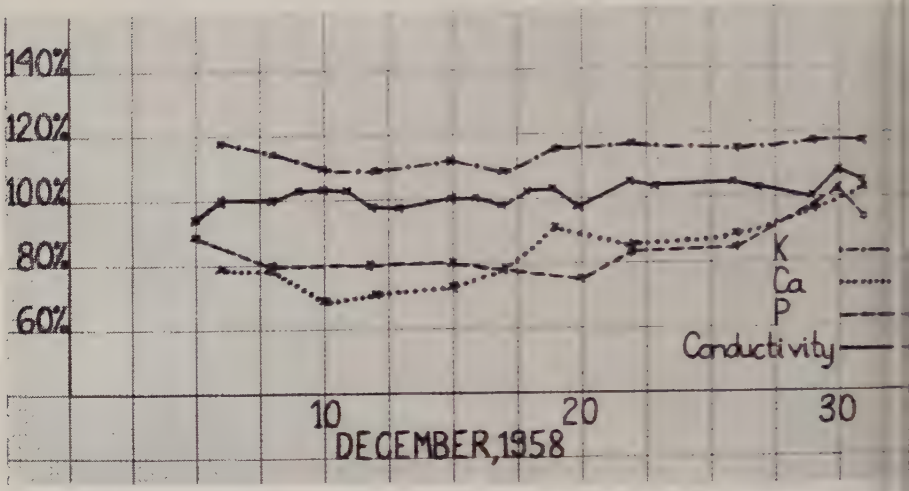

Figure 2.—Relationship between the total concentration* and the concentration of some single nutrients** in a given nutrient solution, expressed as the percentage of a standard (Lago) solution.

*Measured by conductivity bridge. **Determined by chemical analysis.

others in every respect. Only inconsequential differences were found among the crops grown in different solutions (Lago, modified Lago, Purdue, New Jersey) with respect to their growth, quality, or quantity. (See Table 4)

Reitmeier (9) has claimed that cabbage is among the plants which require sodium for maximum production even in the presence of ample potassium. According to our experience, cabbages did not respond to

TABLE 3.—ADDITIONS OF CHEMICALS* AND WATER REQUIRED TO MAINTAIN A BALANCED NUTRIENT SOLUTION OVER A 150 DAY PERIOD**
(Indirect measurement of plants' uptake)

NO_3	K	P	Mg	Ca	H_2O	Approximate % of plants in each bed
415	235	550	210	620	350	Strawberry 50% Cucumber 35% Cabbage 15%
370	275	475	280	410	260	Lettuce 100%
475	320	625	325	610	430	Tomato 100%
400	270	570	235	500	290	Crucifers 100%
365	255	480	305	450	290	Corn 60%, Broccoli 25% Tomato 15%
535	360	615	330	670	360	Tomato 50%, Bean 50%
			AVERAGE:			
425 (1.5)	285 (1)	550 (2)	280 (1)	540 (2)	330	

*Shown as percentage of nutrients in standard Lago solution.
**From December 1, 1958 to April 30, 1959

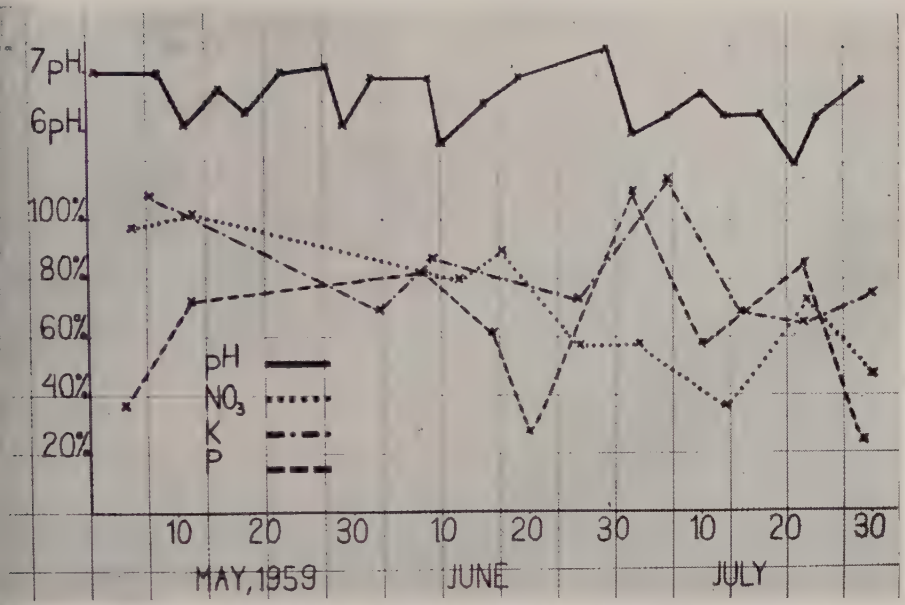

Figure 3 (a).—The changes of the pH and of the levels of NO_3, P and K, in a "new" concrete tank, over a period of three months.

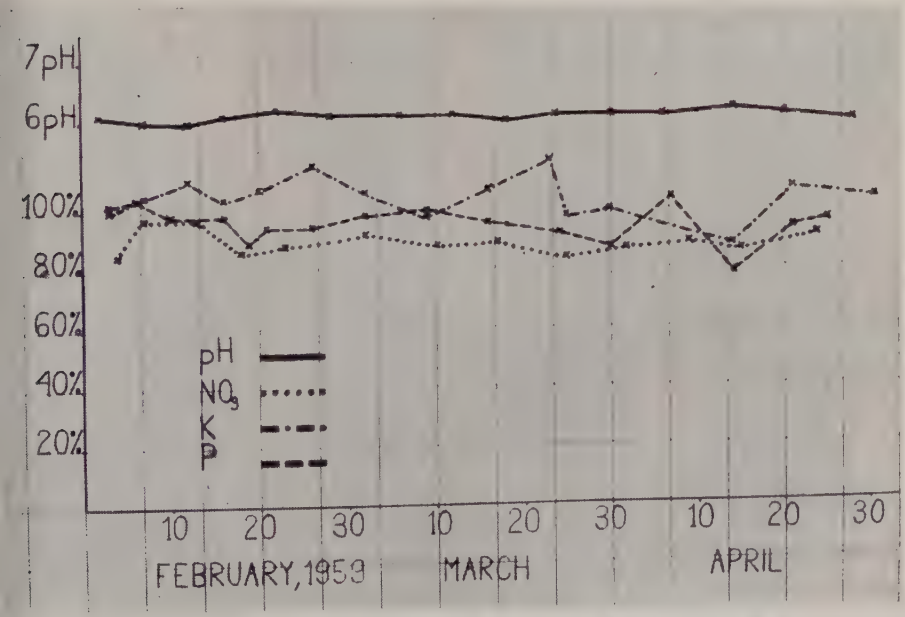

Figure 3 (b).—The changes of the pH and of the levels of NO_3, P and K, in an "aged" concrete tank, over a period of three months.

TABLE 4.—YIELD OF CROPS GROWN IN DIFFERENT STANDARD SOLUTIONS

Type of Nutrient Solution	Crop	Yield in Kg (Fresh Weight)	Planted	Harvested or Removed
New Jersey	Tomato (Indian River)	31	4/21	8/19
Modified Lago (70% of standard concentration)	(Indian River	31	4/21	8/19
Purdue	(Indian River)	30	4/21	8/19
New Jersey	Lettuce:			
	Bibb	2.3	4/10	7/31
	Salad Bowl	1.5	6/19	7/31
Lago	Lettuce:			
	Bibb	3.4	4/10	7/31
	Salad Bowl	1.8	6/19	7/31
Purdue	Lettuce:			
	Bibb	3.4	4/10	7/31
	Salad Bowl	0.9	6/19	7/31
New Jersey	Soybean:			
	Bansei	2.1	4/15	6/15
	Ogden	1.0	4/15	6/15
Lago	Soybean:			
	Bansei	2.2	4/15	6/15
	Ogden	1.0	4/15	6/15
Purdue	Soybean:			
	Bansei	1.7	4/15	6/15
	Ogden	1.0	4/15	6/15

sodium over and above that supplied naturally in the water, in which sodium is about 20 ppm. (Table 5).

CLIMATE AND PROBLEMS OF SHADING

The hydroponic gardens at Stuart have climatic conditions which are partly natural and partly artificial. The air circulation is different from that under open sky in that fans are operated to compensate for the restricted flow caused by double screening. The temperature and relative humidity are slightly influenced, and wind and sunlight much more so, by the construction of the hydroponic enclosures. The rainfall is under absolute control. For these reasons, the hydroponic gardens here have a

TABLE 5.—CROP YIELD AT VARIOUS POTASSIUM:SODIUM RATIOS

K:Na (mM) in the nutrient solution	Crop	Yield in Kg (fresh weight)	Planted	Harvested or Removed
7:0	Cabbage (Copenhagen Market)	18	4/3	7/6
5.5:1.5	Cabbage (Copenhagen Market)	15	4/3	7/6
4:3	Cabbage (Copenhagen Market)	13	4/3	7/6

"transition climate" (7), which is somewhere between that of a greenhouse and that of outdoors.

The new roof construction, mentioned before, eliminated the difficulties formerly caused by rainwater diluting the nutrient solution. A new problem has arisen, however, for the plastic-fiberglass material and its accompanying framing have decreased the amount and intensity of light transmitted through the roof. (See Figure 4).

Over and above the etiolating influence, the decreased supply of light appeared to cause or enhance manganese deficiency symptoms in the plants, particularly in tomatoes, cucumbers and strawberries. It is an old hypothesis that manganese is involved in photosynthesis. Among others, Mulder and Gerretsen (8) concluded that the various and divergent symptoms of manganese deficiency are due to a consequence of a low

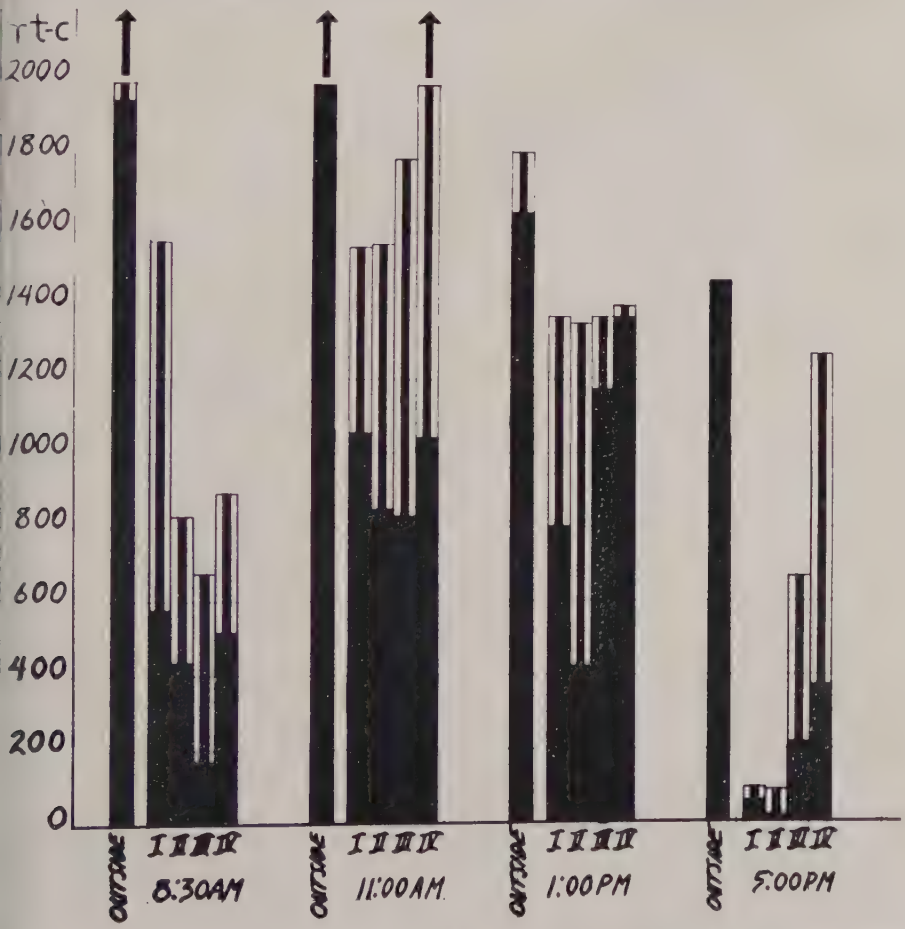

Figure 4.—Light intensities (foot-candles)*, outdoors and inside the hydroponics units I, II, III, and IV during the period from November 3rd to 9th, 1959. Expressed as mean low intensities (completely shaded bars) and mean high intensities (partially shaded bars).

*Measured by a calibrated photoelectric light meter (G.E. Type DW-68.)

carbohydrate level, resulting from low photosynthetic activity.

Trials were made relating to manganese, since it was observed that some of the plants shaded by the roof responded favorably to an increased manganese supply. One series of experiments were run from April to August, at which time the plants were naturally less shaded. There were no important differences in appearance or yield among plants fed by varying Mn solutions (0.4, 2.0 and 10.0 ppm Mn). All the plants showed what appeared to be Mn deficiency symptoms. On the other hand, the *planned* Mn levels never actually occurred in the solution because we found it was not possible to keep either the pH or the level of Mn under control in the new concrete tanks. (See Table 6).

TABLE 6.—CROP YIELD AT VARIOUS IRON:MANGANESE RATIOS

Fe:Mn ppm in the nutrient solution	Crop	Yield in Kg (Fresh Weight)	Planted	Harvested or Removed
1:0.4	Tomato (Indian River)	28	4/21	8/19
1:4	(Indian River)	30	4/21	8/19
1:10	(Indian River)	34	4/21	8/19
1:0.4	Peppers (P. I. varieties)			
	131,352	1.1	5/5	8/19
	167,062	1.2	5/5	8/19
	164,562	0.4	5/5	8/19
	222,133	0.4	5/5	8/19
1:4	131,352	0.9	5/5	8/19
	167,062	1.2	5/5	8/19
	164,562	0.5	5/5	8/19
	222,133	0.5	5/5	8/19
1:10	131,352	0.9	5/5	8/19
	167,062	1.4	5/5	8/19
	164,562	1.0	5/5	8/19
	222,133	0.6	5/5	8/19

CONCLUSION

Many varieties of vegetables can be grown reasonably successfully in conventional hydroponic units, without the use of residual pesticides. Quite elaborate protective measures must be employed, however, to substitute for chemical protection ordinarily provided all crops in this area. Sometimes such protective measures themselves impose conditions within the environment which are not conducive to completely satisfactory growth. We are now in a position to produce limited quantities of pesticide-free crops as controls for further experimentation, and hopeful of further improving our techniques.

APPENDIX

1. *Dimensions of Tanks and Beds*
   a. Units I and II combined are 100′ x 45′
      6 storage tanks are each 6′ x 6′ x 6.25′
      12 beds are each 40′ x 2.5′ x 1′

b. Units III and IV combined are 84′ x 45′
36 storage tanks are each 32″ x 58″ x 23″
36 beds are each 12′ x 2.5′ x 1′

2. Analyses:
   a. Phosphorus determination according to Fiske and Subbarow, J. Biol. Chem. *66* 375 (1925) with Coleman Junior Spectrophotometer.
   b. Sulfate and nitrate determinations according to the methods adapted by Broz. See Ellis, Swaney & Eastwood (2).
   c. Potassium, magnesium, calcium, sodium, manganese determinations employing the flame photometer (Beckman Model DU with photo multiplier and H_2-O_2 flame) and standard solutions of potassium, magnesium and sodium chlorides, calcium acetate, and manganese sulfate. Wave lengths of 770, 371, 423, 389, and 403 millimicrons respectively.
   d. Manganese was separated from interfering potassium by complexing the manganese with dithiocarbamate into carbon tetrachloride followed by hydrolysis and removal into dilute hydrochloric acid, according to a procedure adapted in this laboratory (unpublished data of J. P. Winfree).

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Water Table Fluctuations in Organic Soils of South Florida During Periods of Drainage and Irrigation[1]

DALTON S. HARRISON[2]

INTRODUCTION

Continuous efforts to adequately drain the organic soils of the Florida Everglades have been going on for four decades (5). Since 1949, 128 miles of channels and canals have been dug or improved, 300 miles of levees have been constructed and six pumping stations have been put into operation to serve the dual purpose of flood control and water conservation. These facilities are under operational control of the Central and South Florida Flood Control District, located at West Palm Beach, Florida (6). At the end of ten years, the over-all flood control plan is only 18 percent complete. The ultimate cost of the program will be some $300,000,000. Yet, this cost is insignificant in view of the present annual production of about $50,000,000 worth of fresh winter vegetables, with a potential of supplying the world.

Many problems of farm drainage are still unsolved. With an annual loss of about 1¼ inches of soil due to subsidence (1) and under continuous cropping, the soil becomes compact thus making it more difficult each year for the rapid downward movement of soil water after heavy rains. The result is loss of crop stand due to flooding, even though pumping facilities are adequate. There are doubts about the benefits derived from long accepted practices such as moling.

Recent research data show that the downward movement of the water table is very slow after periods of heavy rainfall. Therefore, much information is needed on the ways and means of increasing the rate of downward movement of the water table in the organic soils of south Florida.

MATERIALS AND METHODS

During 1959, a third attempt was made to determine the actual field fluctuations in water tables after periods of drainage and irrigation (2). A 20 acre tract of land cultivated for the previous 20 years was selected. The dimensions of the field were 650 feet wide x 1320 feet long. The 20 acre field running from west to east was bordered on the north and south by tributary lateral ditches. Three treatments were used: 1. moled on 10 feet spacings, 30 inches deep, 2. non-moled, and 3. moled on 20 foot spacings, 30 inches deep. Moles were run from south to north and pulled out of the ground some 40 feet before they reached the north lateral ditch. Each plot was 650 feet wide x 150 feet long and replicated three times. Four piezometer tubes (3,4) (1½" diam.) were installed in each plot, two at a distance of 200 feet from the south lateral ditch and two 200 feet from the north lateral ditch.

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During periods of drainage and irrigation, the depth to the water table was measured by means of a calibrated float, every five hours, until drainage or irrigation ceased. In addition, four samples of soil were taken from each plot and the organic matter content was determined. Laboratory determinations were made on samples to determine the amount of free water per inch of soil, from samples taken at different depths and placed under varying tensions.

RESULTS AND DISCUSSION

After Drainage: There were no significant differences among treatments in the rate of downward movement of water (Table 1). This can be attributed to the fact that during periods of heavy rainfall, the time required to lower the water in the ditch serving the moles is 20 to 75 hours, depending on the rainfall; therefore, by the time the ditch drawdown is down to 30 inches (mole depth), enough water has already been pumped to take care of the amount of rainfall. Another probability is that lateral movement of soil water in organic soils is practically nil due primarily to the excessively high water table.

TABLE 1.—RATE OF WATER TABLE DRAWDOWN IN IN./HR. DURING THE FIRST 20-75 HOURS OF DRAINAGE

Amount of Rainfall	TREATMENT		
inches	10-Foot Mole Spacing	Non-Moled	20-Foot Mole Spacing
1.00	0.45	0.43	0.41
1.50	0.37	0.38	0.38
1.75	0.28	0.24	0.23
1.75	0.37	0.36	0.34
2.00	0.35	0.37	0.34
2.50	0.35	0.34	0.32
Average	0.36	0.35	0.34

When the results are plotted graphically, the slope of the curve of the water table drawdown is usually uniform, regardless of the amount of rainfall (Fig. 1). However, when the rainfall is extremely light or heavy, the curve has less slope indicating a smaller rate of downward movement of the water table.

After Irrigation: The normal ditch layout used in south Florida will not permit an irrigation rate in excess of ½ inch in 24 hours. When the rate is increased beyond this, the lateral ditches will overflow into the field. The rate of rise of the water table is slightly increased by moling at 10-foot spacings as compared to non-moling or at 20-foot spacings (Table 2).

General: Organic matter content ranged from 84 to 88 percent. Soil moisture determinations gave an average moisture content of 149 percent (oven-dry basis) during the entire test for all three treatments. Samples were taken at least 48 hours after rains. The water holding capacity of the soil at different tensions is given in Table 3.

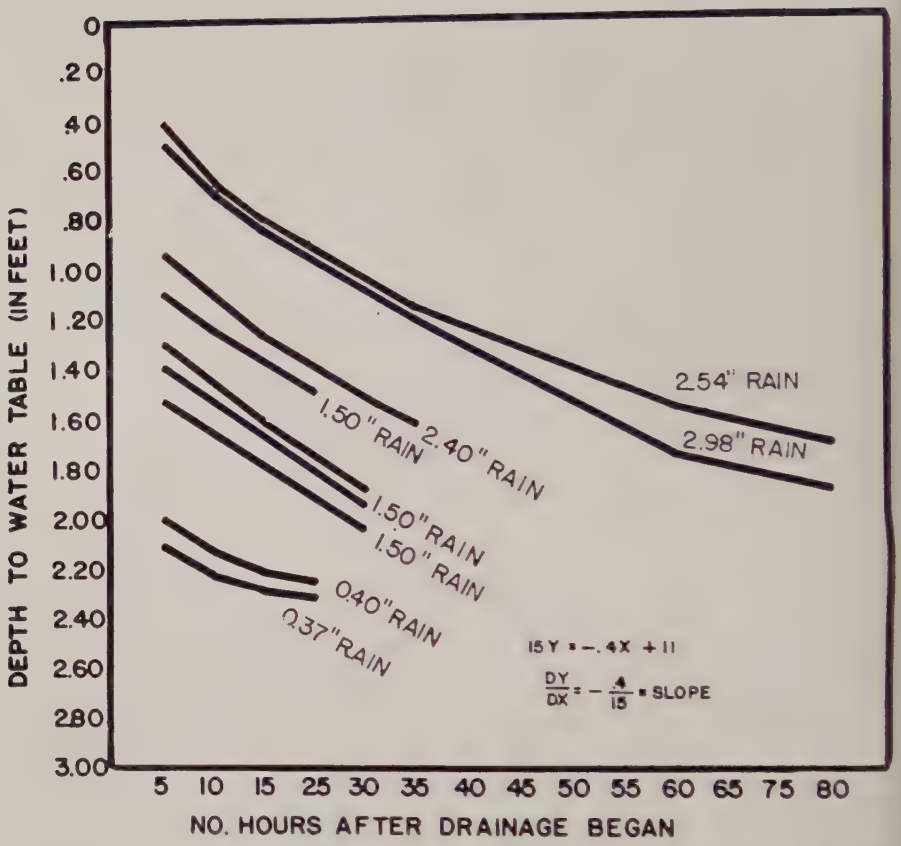

Figure 1.—Water Table Drawdown Characteristics, During Periods of Drainage. (1958-59 data)

TABLE 2.—RATE OF WATER TABLE RISE IN INCHES PER HOUR DURING PERIODS OF IRRIGATION AT A RATE OF ½ INCH PER 24 HOURS

No. Hours Irrigated	TREATMENT		
	10-Foot Mole Spacing	Non-Moled	20-Foot Mole Spacing
20	0.30	0.27	0.27
10	0.23	0.19	0.18
10	0.26	0.19	0.22
15	0.30	0.27	0.25
10	0.41	0.36	0.34
10	0.25	0.21	0.20
15	0.33	0.27	0.27
Average	0.30	0.25	.0.25

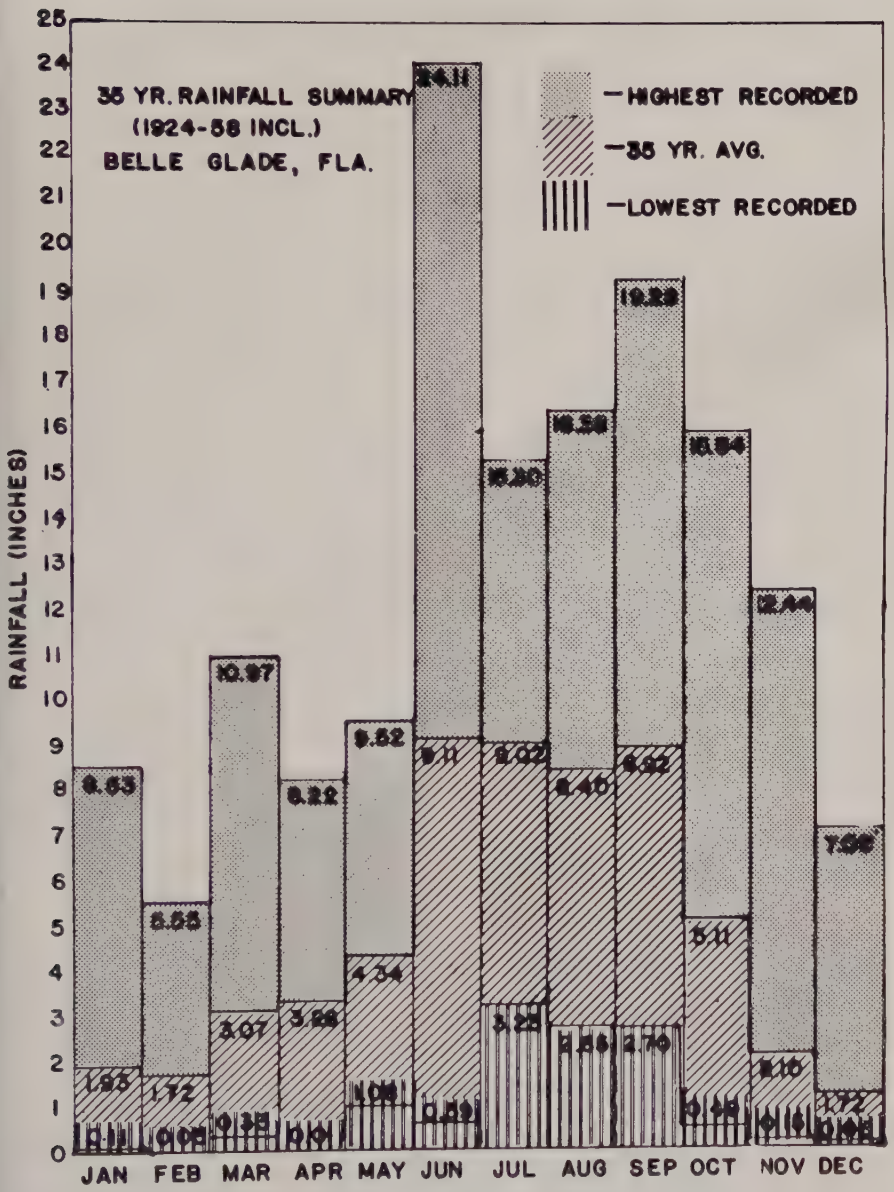

Figure 2.— 35-Year Rainfall Summary for Belle Glade, Florida (1924-58).

SUMMARY

In general the rate of water table drawdown is influenced by the intensity and amount of rainfall, but normally will range from 0.23 to 0.45 inches per hour and averages 0.35 inches per hour. The rainfall for the Belle Glade area is given in Fig. 2. The rate of rise of the water table due to irrigation ranges from 0.18 to 0.41 inches per hour and averages

TABLE 3.—INCHES WATER CONTAINED PER INCH OF SOIL AT DIFFERENT TENSIONS.[1]

Depth	0″	4″	8″	24″	39″	3 atm.	15 atm.
0-3	.844	.755	.695	.605	.585	.530	.420
3-6	.844	.755	.695	.605	.585	.530	.420
6-9	.882	.807	.764	.706	.680	.483	.364
9-12	.882	.807	.764	.706	.680	.483	.364
12-15	.939	.888	.844	.744	.689	.476	.334
15-18	.939	.888	.844	.744	.689	.476	.334
18-21	.922	.882	.850	.752	.700	.330	.214
21-24	.922	.882	.850	.752	.700	.330	.214

[1]Tension in inches of water.

0.27 inches per hour. Maximum rate of irrigation in old soils under cultivation for many years is ½ inch per 24 hours.

Due to the extremely slow rate of water table drawdown during periods of excessive rains (Fig. 2), a pumping plant capacity for drainage in excess of 2.5 inches per 24 hours is not practical for the vegetable farming area in the organic soils of south Florida. On the other hand, an irrigation pump for pumping in should have a capacity of ½ inch per 24 hours. Therefore, a farmer having three pumps in his farm pumping station, needs only one to be reversible, and the capacity of the reversible pump for irrigation need not be in excess of ½ inch per 24 hours.

The rate of water removal from farm pumping also depends upon the elevation of flood control main canals. Excessive elevations in the canals cause seepage, thus making longer periods of pumping necessary. Present flood control plans for pumping during periods of excessive rains greatly aid the farmers in overall pumping efficiency. They eliminate the high heads in flood control canals, once a source of continuous seepage.

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Water Damage to Citrus in the Indian River Area in 1959[1]

R. R. Hunziker[2]

INTRODUCTION

Citrus root distribution in coastal soils is restricted to shallow aerated zones (4). Shallow water tables persistent for long periods seriously restrict root development and overall plant growth. Thus, Ford (1) found that "lowering the water table from 30 to 70 inches doubled the quantity of feeder roots in four years and increased the size of the trees."

The nature of root damage by high water is not clearly defined. Factors which accentuate anaerobic conditions in the root zone and foster certain types of microbial activity in this zone tend to increase such damage. While Klotz and DeWolfe (3) have associated certain California root damage with root rotting by *Phytophthora* spp. of fungi, causal agents in Florida groves may or may not be the same. Ford and Prevatt (2) observed that orange roots may live in non-aerated water under laboratory conditions for as long as one month, without producing new root growth. On the other hand, "steeped" citrus roots produced substances strongly toxic to otherwise healthy roots when these healthy roots were subjected to anaerobic conditions.

In June of this year most of peninsular Florida was subjected to particularly heavy rains. At the Indian River Field Laboratory in Fort Pierce 16.5 inches of rain fell in five days, causing severe damage to established groves in the vicinity. This paper presents results obtained to date from studies of the damage so incurred.

CONDITIONS UNDER WHICH WATER DAMAGE DEVELOPED

On the night of June 14-15, 1959, rainfall was sufficient (3.6 inches) to bring the water tables in groves at and near the Laboratory to high levels. In a low-lying half section northeast of the junction of King's Highway and Orange Avenue Extension (NW ¼ of Section 12 and SW ¼ of Section 1) middles between grove rows were half-filled with water. By the morning of June 19, 16.5 inches of rain had fallen and much of this grove land was completely submerged.

It was not until the afternoon of June 23 that grove middles in this half-section were substantially freed of standing water. By this time several 32-year-old Marsh grapefruit and 23-year-old Temples on sour orange rootstock had begun to wilt strongly, as had a few Pineapple oranges on sour orange. These affected areas had previously exhibited stunted growth, smallness of fruit, and thinness of foliage associated with chronic water damage.

In the water-damaged area heavily defoliated trees were scattered among apparently unaffected trees. In the major grapefruit block a three-row

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strip of nearly complete defoliation paralleled practically undamaged rows.

Soils in the affected area are relatively fine-textured Felda and Manatee sandy loams. Since trees on fine-textured soils had generally been conceded to be less susceptible to root damage than trees on coarse-textured soils (6), this area was watched with considerable interest.

METHOD

To sample feeder roots around affected trees, borings were made with a three-inch inner diameter cylinder auger. Twenty-seven specimen trees were sampled during the last three weeks in July, and additional borings were made in mid-August.

Four borings were taken at the tree drip (canopy edge) of unpruned orange trees and at 6.5′ from the trunk of grapefruit trees and pruned-back orange trees, unless otherwise noted. Roots smaller than one millimeter in diameter were classed as feeder roots. Feeder root segments lacking root bark or whose bark slipped easily from the central cylinder were considered dead.

To determine whether soils under defoliated trees were infested with agents capable of inducing "water damage," whereas soils under non-defoliated trees were not so infested, soils from each location were used to inoculate citrus seedlings' roots. Eight-month-old sour orange seedlings were planted in these soils on August 14 and were then subjected to continuous water-logging. Other seedlings growing in sterilized sand were inoculated by a 1½" layer of this soil prior to flooding.

On November 6 soils from the Temple and Pineapple blocks were tested by another method (3). These soils were muddied to about a 1:1 slurry, and two yellowish-green Hamlin oranges were added to each tray of slurry. The oranges were checked daily for Phytophthora-incurred brown rot. Whenever Phytophthora was not positively identified on the surface of the rotted fruit, interior sections of such fruit were used to inoculate 0.4 ppm streptomycin–potato dextrose agar plates. Thus, soils bearing *Phytophthora* spp. capable of causing citrus root rot were characterized by the brown-rot-inducing function of the Phytophthora.

RESULTS

Grapefruit Block 1

In the Indian River Field Laboratory grove 29-year-old Marsh grapefruit on sour orange rootstock, growing on a fine-textured Felda sandy loam, were defoliated by as much as fifty percent. Water stood in the row middles to near row crown height for three days. Thereafter the water table was within two feet of the crown for a month.

Data presented in Table 1 and in subsequent tables refer to specific case trees, rather than to averages of a group of trees. Degree of defoliation estimates were based on actual counts of leaves on selected branches.

From Table 1, one can see that defoliation occurred in Block 1 when the grapefruit feeder root concentration dropped to less than 13 grams in one square foot of soil. No relationship between soil pH and percent loss of feeder roots was observed, other than an increase in percent loss as one moved from the 0-3" soil layer to the 3-6" layer.

TABLE 1.—ROOT DISTRIBUTION OF SELECTED TREES FROM 29-YEAR-OLD MARSH GRAPEFRUIT ON FELDA SANDY LOAM.

Soil Depth	Tree No. 16 (40% Defoliated) Soil pH	Root Weight* Live	Root Weight* Dead	% Roots Live	Tree No. 17 (Non-defoliated) Soil pH	Root Weight* Live	Root Weight* Dead	% Roots Live
0-3 "	6.2	4.15	5.63	42.4%	6.1	6.99	7.55	48.0%
3-6 "	5.2	.89	4.13	17.7%	4.8	3.00	5.86	33.9%
6-12"	4.5	1.64	1.94	45.8%	4.4	3.14	2.92	51.8%
12-18"	5.0	3.58	5.10	41.2%	4.3	2.61	2.67	49.5%
18-24"	7.6	2.63	3.39	43.7%	7.2	2.94	2.82	51.0%
24-30"		.00	.00			.00	.00	
Total		12.89	20.19	39.0%		18.68	21.82	46.1%

*Root weight in grams of feeder roots per square foot of soil cross-section. Samples were taken from Grapefruit Block I on July 14, 1959.

It is apparent that the high water had not pruned off feeder roots to some critical level, but rather had thinned the roots throughout the rooting zone.

Grapefruit Block II

In a second area 32-year-old Marsh grapefruit on sour orange, growing in a Manatee sandy loam, showed a much lower root concentration at 6.5′ from the trunk than did the above grapefruit (Table 2). These trees had been chronically water damaged, but not acutely damaged previously. By the ninth day of high water, when the water was pumped from the grove, more than 400 trees in a block of some 3000 had wilted badly. Within an additional two weeks these trees were more than 90 percent defoliated.

In this block the water table remained within 24 inches of the bed crown for a month after the rains. Feeder roots were pruned back to shallow depths, with live roots being restricted almost entirely to the top six inches, even on trees whose foliage density was little affected. This is the general pattern of feeder root damage encountered—a loss of feeder roots even at the surface, with mortality increasing with soil depth to the point of complete kill at two feet or less. It is entirely possible that the uniform thinning throughout the profile reported in Table 1 will, with time, give place to this pattern.

In this one instance it would appear that the feeder root loss at this stage had to be at least 70 percent of the original population to cause heavy defoliation of the tree. Subsequent loss to less affected trees probably would have been very heavy if there had been extensive periods of dry weather during the remainder of the summer.

In the general area under study acute damage was generally associated with trees which had previously shown chronic water damage. By way of contrast, non-defoliated trees in this grapefruit block had previously been in poorer condition than the defoliated trees, according to the grower.

Fifteen trees in this block which were buckhorned to three-inch limb diameter or pruned to one-and-one-half inch diameter two weeks after the rain have not developed as satisfactorily as have orange trees similarly

TABLE 2.—ROOT DISTRIBUTION OF SELECTED TREES FROM 32-YEAR-OLD MARSH GRAPEFRUIT ON MANATEE SANDY LOAM.

Soil Depth	Tree No. 34 (98% Defoliated)			Tree No. 33 (90% Defoliated)			Tree No. 35 (5-10% Defoliated)			Tree No. 36 (5-10% Defoliated)		
	Root Weight*		% Roots	Root Weight*		% Roots	Root Weight*		% Roots	Root Weight*		% Roots
	Live	Dead	Live	Live	Dead	Live	Live	Dead	Live	Live	Dead	Live
0-3 "	.28	1.09	20.4%	.96	1.32	42.1%	6.66	5.14	56.4%	16.67	4.03	80.5%
3-6 "	.48	1.02	32.0%	.06	.84	6.7%	.84	2.44	25.6%	.91	1.68	35.2%
6-12"	.00	.80		.33	1.96	14.4%	.00	2.39		.00	1.19	
12-18"		1.73		.00	1.67			2.43			.87	
18-24"		2.18			.60			.91			.46	
24-30"		.39			.15			.00			.28	
30-36"		.01			.22						.00	
Total	.76	7.22	9.5%	1.59	6.76	19.1%	7.62	13.31	36.4%	17.58	8.51	67.4%

*Root weight in grams of feeder roots per square foot of soil cross section. Samples were taken from Grapefruit Block II on July 24, 1959.

pruned the last week in August. Apparently as much as 95 percent defoliation is too great a blow to allow economic recovery.

Sour orange seedlings planted in "good" and "bad" soil taken from this block, and then flooded, reversed the field observations. The "bad"-soil seedlings were about five days behind the "good"-soil seedlings in developing wilt symptoms and in defoliation. When the seedlings established in sand were inoculated with these soils, the rate of wilt and defoliation for plants grown in the two soils was identical.

Pineapple Block

The seriously affected Pineapple trees reported in Table 3 indicate the extreme condition existing where the water table remained within 18 inches of the crown for a month after the rain. Here, and in the Temple block, the water was as high as 18 inches above the bed crown for four or five of the nine days of inundation.

TABLE 3.—ROOT DISTRIBUTION OF SELECTED 23-YEAR-OLD PINEAPPLE ORANGE TREES ON MANATEE SANDY LOAM.

	Tree No. 22. Defoliated. 150 Green Fruit Hanging.				Tree No. 21. 50% Defoliated			
Soil Depth	Soil pH	Root Weight* Live	Root Weight* Dead	% Roots Live	Soil pH	Root Weight* Live	Root Weight* Dead	% Roots Live
0-3 "	4.1	.15	3.04	4.7%	4.4	.04	4.34	.9%
3-6 "	4.2	.07	9.21	.8%	4.4	.00	1.92	.0%
6-12"	5.1	.00	.11		4.8	.09	2.20	4.1%
12-18"			.00		4.9	.00	.00	
Total		.22	12.36	1.8%		.13	8.46	1.5%

*Root weight in grams of feeder roots per square foot of soil cross section.

One fourth of the fruit on the completely defoliated Pineapple tree has retained a greenish tinge, but no flush has appeared on the branches. The 50-percent-defoliated tree is in only a slightly wilted stage, but shows no new flush and only a limited growth of new feeder roots adjacent to the trunk.

Other Pineapple oranges on soil a foot higher than the above trees exhibited no signs of foliar damage until 10 days after the water had been pumped from the grove (as opposed to severe wilt on the above trees and on the Temple trees by the time the water had been removed). In most of the late-wilting Pineapple trees, wilting increased in intensity over an additional two-week period during which defoliation on some trees rose to as much as 90 or 95 percent. Wilting and lack of thriftiness have continued to date despite good moisture conditions in the soil.

Temple Block

A comparison among the root concentrations of Temple trees affected by water to varying degrees is shown in Table 4. While Tree No. 10 still had some firm feeder root bark July 17, it was completely dead by August 14.

The Orlando tangelo listed in Table 4, like many Temples in good condition nearby, was immediately adjacent to seriously injured trees

TABLE 4.—ROOT DISTRIBUTION OF 23-YEAR-OLD TEMPLE TREES ON SOUR ORANGE ROOTSTOCK AND ORLANDO TANGELO ON LEMON ROOTSTOCK.*

	Tree No. 10. Temple 100% Defoliated			Tree No. 12. Temple 95% Defoliated			Tree No. 13. Temple Non-defoliated			Tree No. 11. Tangelo Non-defoliated			Tree No. 12'.**	
Root	Soil	Root Weight*		Soil	Root Weight*		Soil	Root Weight*		Soil	Root Weight*		Root Weight*	
Depth	pH	Live	Dead	pH	Live	Dead	pH	Live	Dead	pH	Live	Dead	Live	Dead
0-3 "	4.2	.08	2.32	7.1	1.27	.71	6.9	.71	.51	5.5	2.00	.31	.10	1.18
3-6 "	4.2	.31	2.82	6.9	.47	1.93	6.8	.46	1.37	5.3	1.69	1.31	.20	.96
6-12"	4.2	1.36	2.82	6.8	1.50	2.34	5.4	.00	.65	4.8	6.12	2.14	.00	1.00
12-18"	4.4	.59	.68	7.3	.32	.74	5.6		.56	5.5	2.11	.30		.04
18-24"	7.0	.92	.35	7.7	.35	.40	7.6		.00	7.6	1.29	.05		.42
Total		3.26	8.99		3.91	6.12		1.17	3.09		16.21	4.11	.30	3.60

*Trees No. 10, No. 11, & No. 12 sampled July 17, 1959. Trees No. 12' & No. 13 sampled August 14, 1959. Soil type intermediate between Felda and Manatee sandy loam.

**Temple No. 12 and No. 12' refers to the same tree.

(No. 10 and No. 12). Unlike most of these non-defoliated Temples, such as No. 13, it retained a particularly vigorous feeder root system. This, and another isolated case of similar nature, argue against the previously accepted belief that lemon rootstock is undesirable for wet soils.

Soils taken from the non-defoliated Temple and Pineapple trees were equally as effective as were soils from defoliated trees in causing brown rot on Hamlin fruit. The first brown rot infestation was observed in a "good" soil tray. Thereafter two additional "good" soil trays and two of the six "bad"soil trays developed Phytophthora colonies.

Soils from the Manatee grapefruit block, the Temple block, and the Pineapple block were tested in August for the presence of nematodes. No Radopholus nematodes were encountered. High counts of Tylenchulus and a few Helicotylenchus were encountered, but no correlation between nematode count and previous defoliation or wilt was obtained.

Contribution of Organic Matter Application to Water Damage

Damage in St. Lucie County in three instances followed the addition of organic matter to the soil surface prior to the rain. Two areas received fairly-high-organic soil fill of two to four inches, whereas another grove of young trees had received a covering of citrus pulp. Heavy tree loss in these cases may have been due merely to anaerobic conditions, or it may be attributable to fostering by the organic matter of an organism such as Phytophthora.

Cultural Practices Aiding Recovery

The pruning of Temples, Pineapples, and Valencias to ¾" or to 1½" the last week in August has given much better initial regrowth than has the buckhorning to 3" or 4". On November 23 the pruned trees appeared to be in much better condition than the check (unpruned) water-damaged trees.

Apparently the tree must have lost less than 95 percent of its foliage and be capable of putting out buds without pruning to be worth salvaging. Even so, seriously damaged trees will not be able to sustain droughts (which were not experienced in this work).

Much of the feeder root growth on recovering trees is within two or three feet of the trunk, suggesting the desirability of light fertilization close to the trunk for maximum recovery.

SUMMARY

Feeder root counts on water-damaged citrus indicate a reduction in the depth of penetration of feeder roots in the more serious cases, and a loss of feeder roots at all depths in all cases. In some moderate cases grapefruit roots were thinned uniformly throughout the profile.

Trees lost more than 50 percent of their feeder roots at the edge of the canopy (drip) before defoliation of the tree became apparent.

Citrus may react to the same type of water damage in a variety of ways. Thus most citrus studied was severely wilted before water had been pumped from the groves, and little additional wilt appeared in these areas thereafter, whereas the Pineapple oranges in large part showed no symptoms until 10 days after the water had receded.

Trees defoliated by as much as 95 percent were beyond economic

recovery. Initial recovery following the cutting back of damaged trees indicated a marked advantage in pruning to $\frac{3}{4}$" or $1\frac{1}{2}$" limb diameter over buckhorning to 3" diameter or larger.

The concentration of feeder root regrowth adjacent to the trunk indicated the desirability of fertilizing close to the trunk once severely damaged trees have begun recovery.

Phytophthora spp. were isolated from soils taken in water-damaged groves. Soils taken from around defoliated trees were no more capable of causing further "water damage" than were soils taken from around non-defoliated trees. Neither were they more capable of infesting fruit with brown-rot-inducing Phytophthora.

Nematode populations of the soils were in no way correlated with degree of water damage to the trees.

Water damage to citrus can be as acute on fine-textured soils as on the coarse-textured soils. Acute water damage on fine-textured soils probably will be preceded in such event by a history of chronic water damage, which will have retarded the growth of the tree to a noticeable degree.

ACKNOWLEDGMENT

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Comparison of Photosynthetic and Respiratory Rates in Some Florida Pasture Grasses[1]

Vincent N. Schroder and O. Charles Ruelke[2]

INTRODUCTION

Pasture production in Florida has increased significantly with the establishment of improved grasses. However, the actual maximum productive capacity of our grasses is not known and most likely has never been reached since the factors necessary for growth are not always present in optimum amounts. In fact, we still have much to learn about the combination of fertilizer, moisture, light, management and other conditions which will produce maximum growth. Yields of 7.5 tons of pangolagrass and 8 tons of coastal bermudagrass in Florida have been reported by Racine and Killinger (4), but almost every year brings reports of still larger yields. With recent developments in instrumentation, we are able to study the growth rate over very brief intervals without harvesting the plant and thereby gain a better insight into the specific effect of certain factors on plant growth. By this means, we hope to find the potential of some of our plants and then work toward achieving this potential.

In the spring of 1959, plots of four commonly used pasture grasses were established on the Agronomy Farm at Gainesville. The 12 foot square plots were located adjacent to each other and separated by alleys three feet wide. The soil was Arredondo fine sand. Each plot was uniformly fertilized with 8-8-8 fertilizer at the rate of 370 pounds per acre. The species used in this study were common bermudagrass, coastal bermudagrass, Pensacola bahiagrass, and pangolagrass.

METHODS

In photosynthesis, carbon dioxide is removed from the air by plants and incorporated into organic compounds with the attendant release of oxygen. Respiration involves the breakdown of organic compounds with the release of carbon dioxide. We can study each of these processes by measuring the amount of carbon dioxide taken up or released by the plant. In this study, these measurements were made with an infrared gas analyzer. Both the instrument and technique of measurements have been described in detail in a previous paper by Schroder (5). This instrument operates on the principle of absorption of infrared energy by carbon dioxide gas and gives almost instantaneous and continuous readings. A mobile climatological laboratory with a self-contained power source was used to house the analyzer and permit its operation in the field. A view of both the plots and the mobile laboratory is shown in figure 1.

When actually measuring the amounts of carbon dioxide given off or taken up due to activity of the plants, it was necessary to enclose the plants

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Figure 1.—View of mobile climatological laboratory and infrared gas analyzer being used to make photosynthetic measurements in grass plots.

in some type of chamber. For this purpose, a satisfactory container was made by cutting a five gallon jar in two and using the top half. The chamber is placed over the plants and the cut edge pushed into the ground to form a seal. Plastic hoses for the circulation of air over the plants and through the analyzer are inserted through a rubber stopper in the neck of the jar. Measurements made in this manner include the carbon dioxide evolved from the soil and plants as well as that furnished from the air.

RESULTS

Photosynthetic measurements reported here cover a period extending from June to November and are given in table 1. The process of photosynthesis is affected by a number of factors including light, temperature, and soil moisture. Notes on these are included in the table.

Respiration measurements were made along with the photosynthetic measurements and are given in table 2.

DISCUSSION

There is a clear and definite trend for photosynthesis and respiration to increase with the warmer weather and to decrease again in the fall, as can be seen graphically in figure 2. Due to many variations of the environmental conditions and also to the stage of growth and condition of the plant itself, we sometimes obtain measurements which are at variance with the general trend. For instance, the low value obtained for photo-

TABLE 1.—PHOTOSYNTHETIC MEASUREMENTS MADE UNDER FIELD CONDITIONS EXPRESSED AS MILLIGRAMS OF CO_2 TAKEN UP PER SQUARE METER PER HOUR.

Grass	6-10-59	6-23-59	7-7-59	7-21-59	9-11-59	10-1-59	11-2-59
Common Ber.	1774	3008	2866	4441	3509	639	1509
P. Bahia	1719	1762	------	3938	3302	1863	1481
Coastal Ber.	1636	1150	2934	4185	3128	1748	1513
Pangola	1606	2554	------	4875	1898*	1140	1857
Light, f.c.	4000	10,000	8300	9400	10,000	8900	6400
Temp. °C.	30	36	32	34	34	33	24
Soil moisture:	fair	excel.	good	excel.	excel.	dry	good

*This value low because cloud cover reduced light to 4400 f.c.

synthesis of common bermudagrass on October 1 is due to a somewhat dried up condition of the grass at that time. More favorable growing conditions reversed this before the next measurements were made. The low reading for pangolagrass on September 11 was due to the cloudy weather reducing the light and resulting in lowered photosynthesis. Light is often below its maximum intensity. Bormann (1) has estimated that in the eastern United States in high summer 44.5 percent of the light may have an intensity above 6,000 foot-candles. Even at this level all plants may not reach light saturation.

In general, it may be said that none of the grasses studied showed a clear-cut superiority over the others. Common bermudagrass had slightly higher rates of photosynthesis and respiration. Although this seemed surprising, work by Peele (3) in South Carolina showed a yield of 9.71 tons of hay from common bermudagrass with irrigation and high nitrogen fertilization. Coastal bermudagrass under identical conditions yielded 10.56 tons of hay. This yield of 9.71 tons indicates that common bermudagrass has a tremendous potential which is seldom realized. It is not implied that common bermudagrass should be planted rather than the improved varieties, since under unfavorable drought conditions with the same amount of fertilizer the yield was only 0.30 tons and coastal bermudagrass outyielded it four to one. A lot more information is needed about the potential yield of many of our crops.

The highest rates of photosynthesis found in this study indicate that approximately 440 pounds of carbon dioxide per acre of grass could be fixed in a 10 hour period of light. About 300 pounds of this should show up as an increase in dry weight. These yields are high, but certainly within the potential of the plants. Daily increases approaching 150 pounds of dry matter per acre have been reported by Brougham (2) from a rye-grass-

TABLE 2.—RESPIRATION MEASUREMENTS MADE UNDER FIELD CONDITIONS EXPRESSED AS MILLIGRAMS OF CO^2 EVOLVED PER SQUARE METER PER HOUR.

Grass	6-10-59	6-23-59	7-7-59	7-21-59	9-11-59	10-1-59	11-2-59
Common Ber.	1041	1410	1104	1960	1008	298	244
P. Bahia	844	1031	------	1827	791	663	240
Coastal Ber.	754	840	1131	1845	626	630	260
Pangola	718	1165	------	1892	706	403	574
Bare soil	312	425		746	------	------	157

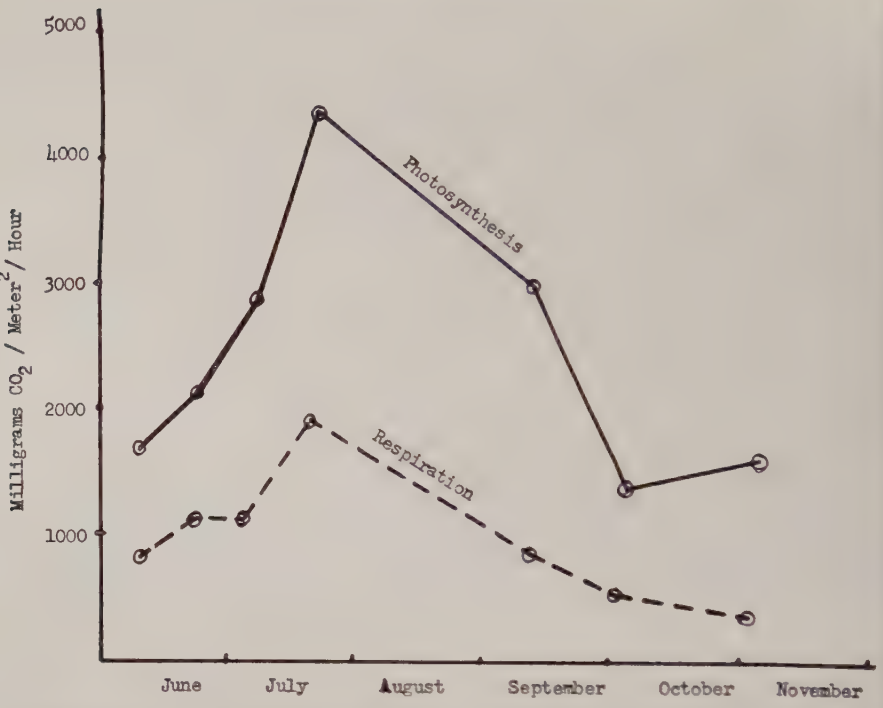

Figure 2.—Seasonal variation in average photosynthetic and respiratory rates of four grasses.

clover pasture in Australia. Part of the decrease in respiration as the season progresses may be due to a reduction of the organic matter in the soil.

These measurements were obtained under field conditions where the environment is quite variable. Research is being initiated to study these grasses under greenhouse conditions where more control can be used.

SUMMARY

Photosynthesis and respiration of four pasture grasses were studied under field conditions. None of the grasses in the experiment exhibited a clear-cut superiority over the others under the conditions of the experiment. All of the grasses indicated much higher potential yields than have been reported to date.

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Pasture Grasses found Suffering from Phosphate Deficiency on Virgin Everglades Peat Soil

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It is well known that organic soils are inherently high in nitrogen and low in potassium, but the phosphate status is variable. In some areas, organic soils have adequate supplies of phosphorus for good plant growth, whereas in other localities, the supply of this element is limited. Waksman (9) and Evans and Allison (4) have shown by analyses that some Everglades organic soils are quite low in phosphorus. Neller and Daane (7) reported a marked response to phosphate in the early history of most crops grown in the area they studied. They pointed out that unless sufficient phosphate was added to the soil, poor feeding value of grasses might result due to their low phosphorus content. Analyses of six virgin organic New York soils by Staker and Jornlin (8) showed they contained somewhat more phosphorus than certain organic soils in the Everglades. It was related by Allen and Kidder (1) that in Florida, phosphorus is usually present and available in virgin muck and peat soils in sufficient quantity to produce normal plant growth. Forsee (5, 6) mentions that virgin Everglades peat soils in most cases contain sufficient phosphorus for most vegetable crops; also, enough of this element is present to support maximum grass growth. As these same virgin soils become more thoroughly decomposed they develop some phosphate fixing characteristics. Bray (2) states that highly organic soils contain large amounts of organic phosphorus though most of it is classed in the difficultly-soluble fraction.

This paper presents the results of two experiments carried out on an extremely phosphate-deficient peat soil in the Everglades. It was decided to publish these data because of the severity of the deficiency and due to the fact that large areas of this type of land, possibly having similar deficiencies, will be going into pasture production as the water control program in South Florida progresses. Paragrass, Pangolagrass and St. Augustinegrass were planted in Sections 13, 14, 18 and contiguous sections some seven miles southeast of Clewiston during the summer of 1952 and were fairly well established by the summer of 1953. These pastures, especially the Paragrass pastures, did not have good color nor did they yield the large quantities of grass expected, based on experience with other organic soil pastures. After one grazing, it was apparent something was definitely wrong since some of the grass never recovered and the rest recovered extremely slowly. Growth in the spring of 1954 and 1955 was much slower than normal, and the slow growth rate continued throughout the entire two years. In 1955 a fertilizer trial was established in the area to try to determine the cause of the poor growth. The stands of Paragrass and Pangolagrass were more severely affected than the St. Augustinegrass, but even the latter was definitely dying out and showing deficiency symptoms.

MATERIALS AND METHODS

Over one thousand acres of virgin sawgrass peat soil in the area mentioned above was cleared, plowed and disked a few months prior to the

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planting by vegetative propagation of St. Augustinegrass, Paragrass and Pangolagrass. During July 1952, the fields received 125, 50, 27 and 15 pounds per acre of KCl, $CuSO_4$, $MnSO_4$ and $ZnSO_4$ respectively. No phosphate was added. Subsequent yearly fertilizer treatments included 25 lbs. per acre of triple superphosphate. It was thought that the soil would supply sufficient phosphate for the establishment of a permanent pasture, since experiments with sugar cane in a near-by area showed no response to phosphate during the first two years of growth. However, since that time, it has been found that most varieties of sugar cane then being grown in South Florida had low phosphate requirements.

A site for the experiment was selected so that all the plots could be located on a fairly good stand of grass. In the spring of 1955, a paired trial containing 12 replications, each plot being 0.152 acre in size, was established on a St. Augustinegrass pasture. Each treatment received 40.5 pounds per acre of P_2O_5 in the form of triple superphosphate and each corresponding check received no fertilizer. The plots were fertilized June 15, 1955. Only one harvest was planned so the grass was allowed to grow until August 7, 1955, when a strip 20 in. x 100 ft. was cut with a Hoffco Power Scythe and weighed.

Between 1955 and 1957, 180 pounds per acre of triple superphosphate was applied to the area.

On August 20, 1958, a six-replicated paired trial was established on a Pangolagrass pasture about one-half mile from the previous experimental site. This experiment and its treatments were located on the exact site of a very similar trial conducted in 1955 that was abandoned because of extensive aphid damage. The treated plots were 0.046 acre in size and received 36 pounds P_2O_5 per acre, whereas, the checks had no treatment. On October 9, 1958, a strip 20 in. x 100 ft. was harvested from each plot.

After the plots were harvested in both experiments, soil samples 7 inches deep were taken with a soil tube, and were analysed for acid-soluble, adsorbed and total phosphorus. Bray and Kurtz (3) method for extracting acid-soluble and adsorbed phosphorus was used, but instead of shaking for 40 seconds the samples were allowed to stand 10 minutes and shaken 5 minutes.

RESULTS

Two weeks after fertilizing on June 15, 1955, a visual response to phosphate was observed. The treated plots were more vigorous in appearance and had a darker green color. Within a month, the dark green color was pronounced and a growth response was visually obvious. On closer inspection, the reddening of the stems and leaves had been greatly reduced and most of the dead-looking leaves had been replaced by healthy ones. The treated plots stood out as dark green strips in every replication and appeared visually very much like nitrogen response on sand as illustrated in Figure 1. The data in Table 1 shows that on an air-dry basis there was a weight increase from 17.3 to 57.8 percent, due to addition of phosphate, with an average of 31.4 percent. It was also evident that there was a greater increase over the check on the green-weight basis than on the air-dry basis. This was due to the higher moisture contents of the grass from the treated plots compared to the grass from the check plots. Ninety pounds per acre of triple superphosphate caused an increase in grass production that was highly significant, as shown in Table 2. In all but one

Figure 1.—Pangolagrass growing on a virgin phosphate deficient peat soil responding to 80 pounds per acre of triple superphosphate. The treated area on the left turned dark green and grew vigorously. (The picture was taken 4 weeks after the phosphate application).

case, the difference in treatment over the check was above the L.S.D. at the 5 percent level of .24 tons per acre on the air dry basis.

In another fertilizer trial conducted in 1955 on the same pasture as that employed in the first trial, using all the essential elements except iron,

TABLE 1.—PAIRED PHOSPHATE FERTILIZER TRIAL ON SAINT AUGUSTINEGRASS PASTURE
Fertilized 6-15-55. A 20" x 100' strip was harvested from each 0.152 acre plot 8-7-55.

Rep. No.	Weight of Air Dry Forage		Diff.	Increase Over Check	Weight of Fresh Cut Forage		Diff.	Increase Over Check
	P*	No P**			P*	No P**		
	Tons/Acre			%	Tons/Acre			%
1	1.88	1.14	0.74	39.4	6.89	4.03	2.86	71.0
2	1.68	1.19	0.49	35.1	6.09	4.03	2.06	51.1
3	2.37	1.00	1.37	47.4	7.28	3.46	3.82	110.4
4	1.50	1.13	0.37	57.8	8.83	3.27	5.56	170.0
5	1.93	1.31	0.62	18.8	6.62	4.93	1.69	34.3
6	1.68	1.10	0.58	30.3	5.76	3.76	2.00	53.2
7	1.96	1.03	0.93	24.7	4.99	3.39	1.60	47.2
8	1.81	1.47	0.34	32.1	6.78	4.28	2.50	58.4
9	1.78	1.24	0.54	17.3	5.77	4.30	1.47	34.2
10	1.56	1.29	0.27	34.5	6.06	3.53	2.53	71.7
11	1.07	0.86	0.21	19.6	3.44	2.49	0.95	38.2
12	1.31	1.05	0.26	19.8	4.67	3.41	1.26	37.0
Average	1.71	1.15	0.56	31.4	6.10	3.74	2.36	64.73

*Phosphorus was added in the form of 90 pounds per acre triple superphosphate top dressed.

**No phosphorus added.

TABLE 2.—STATISTICAL ANALYSIS FOR 1955 AND 1958 EXPERIMENTS

Expt.	"t" at '05 level		"t" at .01 level		.05
Year	Required	Obtained	Required	Obtained	L.S.D.
1955	2.074	5.171	2.819	5.171	.24
1958	2.228	3.280	3.169	3.280	.46

no response was obtained from any of the major or minor elements other than phosphorus.

Between 1955 and 1957, 180 pounds per acre of triple superphosphate was applied to the entire area. The stands of Paragrass, Pangolagrass and St. Augustinegrass were in fair condition, but not as dark green nor as productive as they should have been.

The second paired phosphate trial, which was conducted on a Pangolagrass pasture in the same general area, was fertilized August 20, 1958. Within a week, the treated plots were definitely a darker green color; and, in two weeks, an increase in growth could be observed. Fifty days after fertilizing with phosphate the grass was harvested from both the treated and check plots, and the increase in grass production due to the addition of phosphorus can be seen in Table 3. Again there was a highly significant difference in phosphate treated plots over their corresponding checks. The percent increase on a dry weight basis ranged from 18.2 to 80.0, averaging 53.2. The L.S.D. at the 5 percent level on the air dry basis was 0.46 ton and only in one instance was the difference between treatment and check below that required for significance.

From the soil analysis data in Table 4 it can be seen that the soil in question is a low mineral acid organic soil, very low in total and available phosphorus. The same table shows that in the 1958 experiment the total phosphorus level had increased in the treated plots, whereas, the level of available phosphorus had not increased. This indicates that there is undoubtedly some phosphate fixation taking place.

TABLE 3.—PAIRED PHOSPHATE FERTILIZER TRIAL ON PANGOLAGRASS PASTURE
Fertilized 8-20-58. A 20" x 100' strip was harvested from each 0.046 of an acre plot 10-9-58.

Rep. No.	Weight of Air Dry Forage		Diff.	% Increase Over Check	Weight of Fresh Cut Forage		Diff.	% Increase Over Check
	P*	No P**			P*	No P**		
	Tons/Acre				Tons/Acre			
1	2.3	1.7	0.6	35.3	8.7	5.5	3.2	58.2
2	1.8	1.1	0.7	63.6	7.7	3.4	4.3	126.5
3	1.8	1.0	0.8	80.0	7.9	3.4	4.5	132.4
4	1.3	1.1	0.2	18.2	6.3	3.9	2.4	61.5
5	1.6	1.1	0.5	45.5	6.8	3.2	3.6	112.5
6	1.6	0.9	0.7	77.8	7.4	3.5	3.9	111.4
Average	1.73	1.15	0.58	53.4	7.47	3.82	3.65	100.4

*Phosphorus was added in the form of 80 pounds per acre triple superphosphate top dressed

**No phosphorus added.

TABLE 4.—*SOIL ANALYSIS OF SAMPLES FROM PAIRED PHOSPHATE FERTILIZER TRIALS

ocation l Time of iosphate periment	Treatment Lbs./Acre T.S.P.	Acid Soluble[b,c] and Adsorbed P Lbs./Acre 7" Depth[a]	Total[d] P Lbs./Acre 7" Depth[a]	pH	Organic Content	Mineral Content
dry County, ge 34, nship 44, on 14 15-Aug. 7,						
	90	3.0	100	5.7	91.2	8.8
	0	2.2	93			
dry County, ge 34, nship 44, on 12 20-Oct. 9,						
	80	2.6	141			
	0	2.6	100	5.7	89.1	10.9

All data based on averages of 6-12 replications.

[a] An acre 7" of this type of soil oven dry weighs about 200,000 pounds based on done by C. B. Evans and R. V. Allison (4).

[b] Bray and Kurtz (3) extracting solution for acid soluble and adsorbed phosphorus used.

[c] Available phosphorus was determined by the stannous chloride ammonium molyb- method.

[d] Total phosphorus was determined as molybdevanadophosphoric acid.

SUMMARY AND CONCLUSIONS

The pasture grasses grown on the virgin sawgrass peat soil studied e definitely suffering from a phosphate deficiency. The addition of 0 pounds per acre of triple superphosphate alleviated the deficiency and porarily increased the yields. Soil samples taken after harvesting wed that acid soluble and adsorbed phosphorus levels had not increased he area where the phosphorus had been added, whereas total phos- rus levels had been increased. Based on the results of experimental ls and soil analyses to date, an initial application of at least 36 pounds acre of P_2O_5 followed by annual applications of over 36 pounds of P_2O_5 have to be applied to this type of low mineral Everglades peat soil stablish and maintain a pasture in a good productive state. Probably nuch as 72 pounds per acre of P_2O_5 will have to be applied each year a number of years to build up a reserve in the soil. When over 36 nds per acre of P_2O_5 are applied, it might be wise to use split appli- ons, since there is a good possibility that unless this is done, much of phosphorus added in one application may be tied up in unavailable ns.

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Iron Chlorosis in Roselawn St. Augustine Grass Growing on Muck Soils of the Everglades[1]

FERDINAND LE GRAND[2]

Roselawn St. Augustine grass is a creeping, rather coarse, perennial grass that is used in the Everglades for grazing. Also several thousands of acres are sold annually as sod to the landscaping industry. St. Augustine grass is usually propagated by sprigging or sodding and the creeping, flat stems root, forming a dense sod that will stand intensive tramping.

Everglades muck and peat soils have been shown to be deficient in Cu, Mn, Zn, and B; a high pH causes elements as Mn and Zn to become less available to the plant (1), (2), (3). Consequently most of these minor elements are usually included in the regular fertilizer program.

Kretschmer has reported values for minor element contents of St. Augustine grass leaves (3).

In the spring of 1959 several hundred acres of sod in the Hillsboro Drainage District showed visual chlorosis. Nutritional sprays with urea, phosphate, potash, copper, manganese, zinc, and boron did not improve the color of the chlorotic leaves. However, a nutritional spray of 4 pounds per acre of an iron compound to the St. Augustine grass resulted, in two weeks, in healthy green leaf blades. Green and Stoner (4) reported the first iron deficiency in the Everglades. They obtained increased rice yields by a soil application of iron sulphate.

EXPERIMENTAL

An experiment with four replications was initiated to determine the optimum foliar Fe requirement of St. Augustine grass under these conditions

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The plots were sprayed with Nu-Iron[3] at the rate of 2, 4, and 6 pounds per acre. Soil samples were taken at the same time, which showed an average pH value of 5.6, with a phosphorus content of 4 pounds of water soluble P per acre 6 inches and 23 pounds of 0.5*N* acetic acid soluble potassium per acre 6 inches, as indicated by the Everglades Experiment Station routine soil test.

The soil sample results do not suggest reason for any major deficiency. The pH of 5.6 is considered satisfactory for the availability of minor elements.

Five weeks after the application of the Nu-Iron, leaf samples were taken from each plot. Chemical analyses were made from the leaf blade material, dried at 75° C in a forced draft oven. The leaf blade samples were ground in a nylon roller mill to avoid minor element contamination and were analyzed for P, K, Ca, Mg, Mn,[4] Fe,[4] Cu,[4] and Zn.[4] The data are reported as percentage or ppm dry weight. (Table 1)

TABLE 1.—THE MINERAL CONTENTS OF ROSELAWN ST. AUGUSTINE GRASS LEAVES AS AFFECTED BY FOLIAR APPLICATION OF NU-IRON

Element	Foliar application of Nu-Iron in lbs/acre				
	0	2	4	6	10
	Average mineral content of leaves (4 plots per sample)				
%P (1)	0.435	0.385	0.380	0.335	0.315
%K	2.95	2.77	2.95	2.28	2.45
%Ca	0.55	0.64	0.60	0.45	0.63
%Mg	0.25	0.27	0.30	0.29	0.36
ppm Fe (1)	76	115	139	154	195
ppm Cu	31	26	25	37	31
ppm Mn	75	60	63	49	57
ppm Zn	27	25	25	27	25

(1) Significant at the 1% level for all treatments when compared with check plots.
(2) Analyzed as taken from the field, leaf blades only.

Six days after the application of Nu-Iron all plots that had previously shown deficiency symptoms were recovering and had green areas on the leaf blades. The green dots were probably areas where the spray droplets with the Nu-Iron had hit the leaves. As time progressed, these spots enlarged until finally the whole leaf turned completely green.

Sixteen days after the application, all plots that had received 4, 6, and 10 pounds of Nu-Iron per acre had a dark green color. However, 21 days elapsed before the grass in plots receiving 2 pounds Nu-Iron per acre changed color completely. The plots that had received 6 and 10 pounds Nu-Iron per acre showed some symptoms of leaf burn two days after the foliar application.

At the time of sampling the check plots (0 treatment) showed definite symptoms of iron deficiency. The plots of 2 pounds Nu-Iron per acre had returned to a pale color, while all the plots that received 4, 6, and 10 pounds of Nu-Iron per acre had a healthy green color.

The differences in iron content were highly significant with an F value

[3]Supplied by the Tennessee Corporation, 30% Fe, of which half is chelated.
[4]Analyses by the Tennessee Corporation, College Park, Georgia.

of 15.7, indicating increased amounts of Fe were absorbed as rates of Nu-Iron were increased.

The decrease of the percent phosphorus in the leaves was also highly significant with an F value of 9.5 as levels of Nu-Iron were increased.

Kretschmer analyzed Roselawn St. Augustine grass and found a range of 27 to 70 ppm Fe with an average of 39 ppm, with no iron deficiency symptoms. He suggested that there seemed little possibility of iron deficiency in forages grown on organic soils, (3).

However, the check plots, with the iron deficiency symptoms and having a satisfactory level of Fe as found by Kretschmer (3), responded readily to an iron application.

Using the phosphorus: iron ratio for St. Augustine grass, healthy plants were found to have a ratio of less than 29:1, a pale color in the leaves developed with a ratio between 29:1 and 40:1. Plants having a P:Fe ratio of more than 40:1 showed severe symptoms of iron deficiency. Values for the P:Fe ratio, ppm Fe, and percentage P in leaves are reported in Figures 1 and 2.

While the P:Fe ratio in the leaves decreased with the foliar application of Fe, the Mg:K ratio, on the contrary, increased significantly as a result of the same iron application with an F value of 5.1.

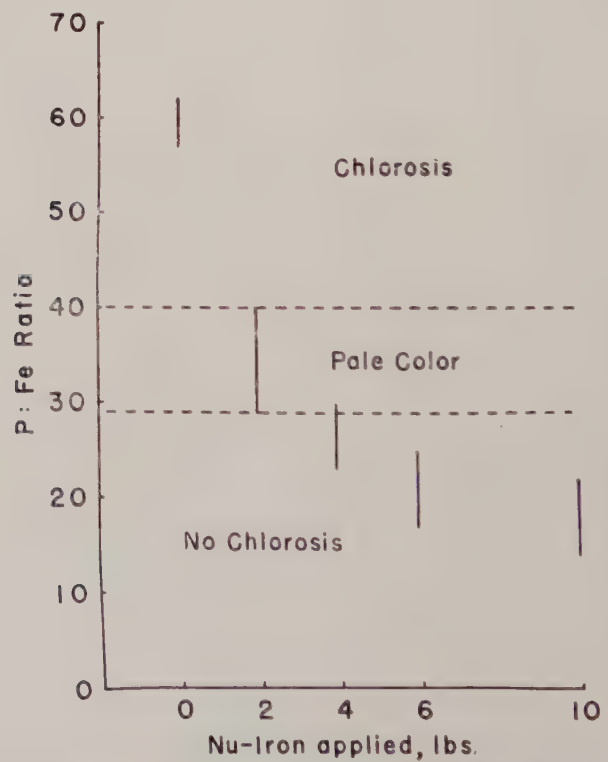

Figure 1.—The effect of the P:Fe ratio on the chlorosis of Roselawn St. Augustine leaves.

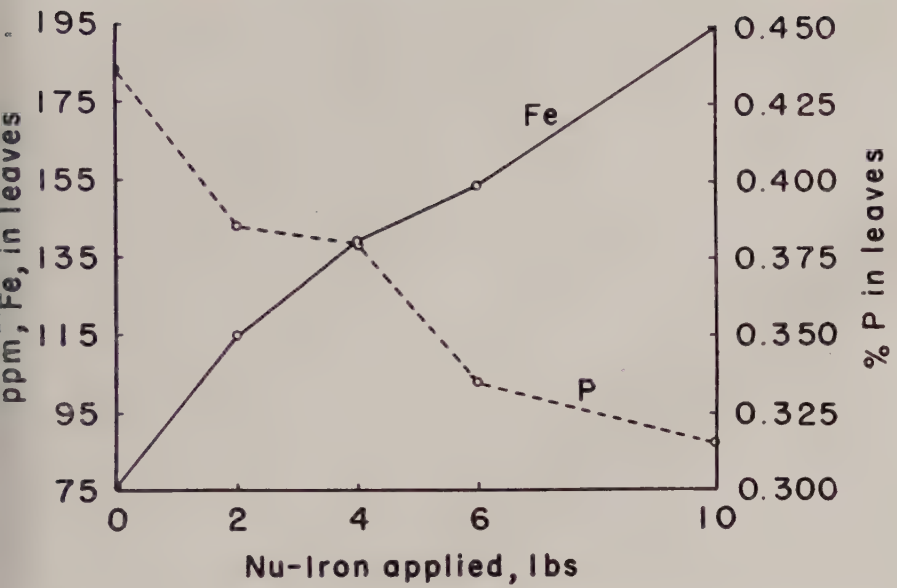

Figure 2.—The effect of Nu-Iron additions on the iron and phosphorus content of Roselawn St. Augustine leaves.

TABLE 2.—THE MAGNESIUM TO POTASSIUM RATIO IN THE LEAVES OF ROSELAWN ST. AUGUSTINE GRASS AS AFFECTED BY A NU-IRON APPLICATION.

	Nu-Iron applied, lbs./A.				
	0	2	4	6	10
Mg:K ratio	.085	.097	.103	.127	.147

Discussion:

DeKock (5) and DeKock and Hall (6) observed that the leaves of iron deficient chlorotic plants invariably contained more phosphorus than did normal green plants. They felt that iron in chlorotic plants was immobilized as insoluble ferric phosphate.

Under conditions here it would appear that chlorotic and green plants of Roselawn St. Augustine grass can be distinguished from each other by their phosphorus:iron or magnesium;potash ratio.

The decrease of the phosphorus:iron ratio has been brought about by an increase in the amount of iron and a decrease of the amount of phosphate in the leaf. DeKock and Hall (6) suggested that as the iron chlorosis in the leaf decreases, phosphorus apparently migrates out of the leaf and magnesium moves in.

Summary

The first symptom of iron deficiency in Roselawn St. Augustine grass is yellowing of the leaves between the veins, while the veins remain green. As the deficiency progresses, the entire leaf becomes yellow and later dies.

St. Augustine grass suffering from a lack of iron will not produce a normal sod, leaving brown spots in the field.

The data indicate that the ratio of phosphorus to iron in the leaf blades of Roselawn St. Augustine grass should be maintained below 30 to prevent chlorosis. When chlorosis occurs, 1.2 pounds of iron per acre, preferably in chelated form and applied as a foliar spray, will lower the phosphorus:iron ratio by increasing the iron content of the leaf and decreasing its phosphorus content. Under the conditions reported, 4 pounds of Nu-Iron sufficed. The foliar application of iron, lowering the phosphate:iron ratio in the leaves, will also simultaneously increase the magnesium:potassium ratio.

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The graphs were drawn by E. King, Jr. and photos are by H. P. Ruffolo.

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Recovery of Nitrogen from Several Sources by Oats and Millet[1]

G. M. Volk, W. H. Kelly and W. G. Blue[2]

There is considerable controversy over the merits of readily available sources of nitrogen as compared to those having a significant portion of their nitrogen in relatively insoluble or slowly available forms. The problem becomes more pertinent as the costs of natural organic fertilizers increase as compared to those of soluble sources, and with the advent of the new ureaform types of slowly available nitrogen compounds made by interaction of urea with formaldehyde.

The general interest in the insoluble forms arises primarily from a desire to provide extended availability of nitrogen to plants in order to reduce the need for supplemental nitrogen after initial fertilization. A less recognized factor, but one of equal importance in certain usages, is the reduction of luxury consumption of nitrogen by plants immediately after fertilization. Luxury consumption usually is followed by very rapid growth with possible deleterious after-effect. This flush of growth is particularly undesirable with field crops or ornamentals in which uniform vegetative production is desired rather than termination in a seed or fruit crop.

Published data have left doubt as to the logic of recommending slowly available sources of nitrogen (3, 5, 6,), except possible for a few very specialized crops. There is evidence that under average conditions the period of extended availability of nitrogen from soluble sources, after the initial flush of growth, approaches that of the more slowly available sources. The reason probably lies in the role of soil microorganisms. They tend to utilize nitrogen in competition with the plant in the initial stages and release it later as energy sources such as cellulose are depleted and the biological population is reduced or shifted in makeup.

It was the purpose of this study to obtain additional information on sources, amounts, and timing of nitrogen applications to oats and millet on typical Florida light sandy soils by the use of both field plots and greenhouse tests.

EXPERIMENTAL

Field plots were laid out on Ona fine sand at Gainesville, and on Klej fine sand at Live Oak. The original intention was to carry out the tests in quadruplicate with a split-plot design for partial refertilization, but because of the nature of responses to weather and materials the original plan was not followed and certain combinations of plots were made which resulted in the type of data presented in the tables to follow. All data are the average of at least four replicates.

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[1]This work was planned and partially completed by W. H. Kelly with the assistance of W. G. Blue. Analyses of field plot samples and preparation of the report were by the senior author. Fla. Agric. Exp. Sta. Jour. Series No. 1013.

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The initial pH of Ona fine sand averaged 4.79 and of Klej fine sand 5.86. Dolomite was applied at the rate of one ton and two tons per acre to the Klej and Ona soils respectively. A 0-10-20 fertilizer was used to supply 100 pounds of P_2O_5 and 200 pounds of K_2O per acre, along with 50 pounds of general purpose minor element frits. Nitrogen sources consisted of ammonium nitrate, urea, ureaform (Borden's 38) and cottonseed meal.

The oats or millet were drilled first, followed by application of the nitrogenous materials. These materials were surface applied, except for the cottonseed meal which was hoed into the soil. Treatment and retreatment dates, and planting and harvest dates are given in Tables 1 and 2. The harvested area per plot was approximately 55 square feet. The yield was weighed and a representative sample taken for moisture correction to 70° C. dry weight and analyzed for total nitrogen.

Another phase of the work was carried out in the greenhouse using Lakeland fine sand in 2-gallon glazed pots. Materials used in the tests are listed in Table 3. Except for the solutions, all materials were incorporated in the soil. Oats were planted first and cut twice, followed by millet which was cut only once. The two cuttings of oats were analyzed for total nitrogen but yields only were taken for the millet.

RESULTS AND DISCUSSION

Data on field tests presented in Tables 1 and 2 indicate that the recovery of nitrogen by oats following initial treatment was considerably higher for ammonium nitrate than for urea at the 25 and 50 pound rates of nitrogen application. They appear about equal for the 100 pound rate. The same order of response holds for subsequent crops following retreatments with these materials. As presented in Table 3, the responses to these materials in the greenhouse tests do not show this difference.

Data in Table 4 summarize the relative percentage recoveries of nitrogen from urea and ammonium nitrate given in Tables 1 and 2. An overall percentage recovery figure, approximated by listing the data in the manner of Table 4, shows 53.9 percent average recovery from urea as compared to 72.8 percent average recovery from ammonium nitrate for the two lighter rates of nitrogen used at the various times. In contrast, the recoveries from the 100 pound rates were similar for urea and ammonium nitrate. They were only 45.6 percent and 47.0 percent respectively. This relatively low percentage recovery at the 100 pound rate suggests that the nitrogen requirement for the crops had been exceeded and any differential due to source was not limiting to crop growth. The rainfall during the tests was abnormally low and may partially account for the low recovery of nitrogen.

The responses to synthetic insoluble sources of nitrogen were very low with initial crops, but the residual buildup of nitrogen from these materials gave a more favorable response on successive crops. Part of the reason for the poor initial recovery in field tests might have been the result of surface application of the synthetic insoluble materials. This would tend to give them poor contact with active microflora in the soil.

The recovery of nitrogen from soluble sources in the greenhouse was relatively uniform at about 58 percent. Initial recovery from cottonseed meal and milorganite was about one-half that from soluble sources, with somewhat improved recovery showing up with recropping. An exception was castor pomace, from which the relative recovery was higher than

TABLE 1.—YIELD AND NITROGEN RECOVERIES BY OATS AND MILLET (Ona fine sand at Gainesville)
(Data are averages of at least 4 replicates on per acre basis, 70°C dry wt.)

Treatments in Lb. N/A 10/30/56		Oats Cut 4/5/57		Retreatment* 4/6/57 Lb. N/A	Millet Cut 5/21/57		Millet Recut 6/13/57		Millet Recut 7/18/57		Total Recovery by Millet	Retreatment** 7/23/57 Lb. N/A	Millet Cut 8/28/57		Retreatment 12/10/57 Lb. N	Oats Cut 4/21/58	
		Yield Lb.	Lb. N		Yield Lb.	Lb. N	Yield Lb.	Lb. N	Yield Lb.	Lb. N	Lb. N		Yield Lb.	Lb. N		Yield Lb.	Lb. N
Check		2969	48.4	-----	1334	20.0	1527	19.6	1274	9.3	48.9	-----	930	16.5	-----	1417	15.8
Ammonium Nitrate	25	3294	61.8	25	2461	45.5	1346	19.2	1058	7.6	72.3	50	2108	59.1	50	1385	21.0
	50	3645	70.3	none	2188	37.2	1563	19.0	1130	7.9	64.1						
				50	3870	93.4	1515	23.1	1346	9.5	126.0	100	2633	87.5	100	1273	20.7
	100	3681	80.8		2582	48.9	1707	26.7	1514	10.0	85.6						
Urea	25	3205	53.9	25	2789	42.3	1226	17.2	1250	8.8	68.3	50	2060	52.8	50	1462	19.8
	50	3125	63.4	none	2380	37.3	1587	19.7	1394	9.1	66.1						
				50	2957	68.2	1831	27.7	1082	8.8	103.7	100	2610	84.7	100	1491	21.9
	100	3678	81.8		2668	51.2	1899	34.6	1490	11.1	96.9						
Urea-form	25	3137	50.8	25	1988	28.7	1707	20.4	1346	9.7	58.8	50	1608	34.0	50	1371	18.8
	50	3078	51.8	none	1779	31.1	1394	17.1	1226	8.6	56.8						
				50	2380	37.6	1827	25.7	1370	10.2	73.5	100	1933	44.1	100	1383	22.2
	100	3378	62.2		1755	29.0	1775	22.0	1130	7.7	58.7						
Cotton-seed meal	25	3151	54.8	25	2645	51.5	1731	23.0	1346	8.9	83.4	50	2120	41.4	50	1630	22.1
	50	3163	56.6	none	1899	31.2	1635	21.9	1250	9.0	62.1						
				50	2933	46.4	1683	22.8	1274	8.0	77.2	100	3280	81.8	100	1555	23.9
	100	3781	80.8		2548	42.4	1490	19.9	1418	10.1	72.4						
L. S. D. at .05			13.8			22.9		NS		NS	34.2			14.3			NS

*Original 50 lb. plots split for retreatment.
**Plots having totals of 50 or 100 lb. respectively, combined for respective retreatment of 50 or 100 lb.

TABLE 2.—YIELDS AND NITROGEN RECOVERIES BY OATS AND MILLET (Klej fine sand at Live Oak) (Data are averages of at least 4 replicates on per acre basis, 70° C dry wt.)

Treatments in Lb. N/A 10/27/56		Oats Cut 3/30/57		Oats recut 4/30/57		Total N Recovery by Oats Lb.	Retreatment Lb. N/A 8/1/57*	Millet Cut 9/30/57	
		Yield Lb.	Lb. N	Yield Lb.	Lb. N			Yield Lb.	Lb. N
Check		760	12.0	238	3.7	15.7		355	4.7
Ammonium nitrate	25	1194	21.2	322	4.8	26.0	50	3233	33.6
	50	1364	27.9	357	5.5	33.4			
	100	1195	26.3	557	8.9	35.2	100	4598	70.3
Urea	25	1030	17.8	248	3.6	21.4			
	50	1159	22.8	361	5.3	28.1	50	2963	30.8
	100	1166	27.2	540	8.7	35.9	100	4400	63.8
Urea-form	25	841	13.3	237	3.8	17.2			
	50	920	14.5	236	3.8	18.3	50	1158	12.0
	100	1183	20.2	307	4.8	25.0	100	2433	28.0
Cotton-seed meal	25	922	14.4	269	4.4	18.8			
	50	1122	20.2	307	4.9	25.1	50	1870	18.1
	100	1118	24.2	431	7.4	31.6	100	2963	28.0
L. S. D. at .05			3.8		1.9	4.1			8.14

*Original 25 and 50 pound treatment plots combined for retreatment.

usually measured in tests of this type. The recovery from the ureaforms was about half that from the natural organics.

The differential response to urea and ammonium nitrate in field tests probably can be explained in the light of recent work by the senior author. (8, 9, 10). Measured losses of nitrogen as ammonia gas during seven days time following surface application of 100 pounds of urea nitrogen to light sandy soils with pH values ranging from 4.4 to 6.3 were found to vary from 17 to 59 percent, while losses from ammonium sulfate were only 0.1 to 1.6 percent of the application. Losses from top dressed sods averaged 20 to 30 percent for pelleted and crystal urea respectively and only 0.3 percent for ammonium nitrate. These data provided a logical explanation for results published by Burton and Jackson (2) which showed a relative inefficiency of urea as compared to ammonium nitrate on coastal bermudagrass. Blue and Eno (1) reported a similar discrepancy between urea and ammonium nitrate in certain tests with pearl millet and coastal bermudagrass, but this difference was not apparent with subsequent trials that included limed treatments. They concluded that unfavorable nitrification was the cause of the initial difference in favor of the ammonium nitrate.

It should be pointed out that rainfall occurring within about one week after surface application of urea could have a significant effect on volatile loss by washing any residual urea into the soil. Urea that converts in the soil will show no appreciable loss of ammonia to the atmosphere. This

TABLE 3.—RESPONSE OF OATS AND MILLET TO VARIOUS N-SOURCES IN GREENHOUSE

(2 gal. pots of Lakeland fine sand plus 2000 lb. lime, 100 lb. N, 231 lb. P_2O_5, 200 lb. K_2O per acre and various secondaries. Three replicates)

Nitrogen Sources	Oats First Cutting 7 weeks			Oats Second Cutting 10 weeks		Oats Total		Millet Yield 17½ weeks, Gm.
	Yield Gm.	Gm. N	% N Recovered	Yield Gm.	Gm. N	Gm. N	% N Recovered	
Check	3.51	.082	----	2.4	.040	.123	----	9.3
Sodium nitrate	7.40	.284	53.5	3.9	.081	.365	68.0	9.2
Ammonium nitrate	6.68	.258	46.5	3.4	.067	.325	53.8	7.8
Ammonium sulfate	6.64	.280	52.2	3.6	.054	.334	56.1	8.5
Ammoniated phosphate	7.20	.262	47.6	3.4	.062	.324	53.5	6.6
Urea	6.24	.263	47.9	3.6	.070	.332	55.8	8.5
Borden's 38	4.54	.117	9.1	2.7	.044	.161	10.4	9.9
Nitroform	4.36	.126	11.5	2.6	.057	.187	17.2	5.4
3/4 B 38, 1/4 NH_4NO_3	5.24	.139	14.9	2.6	.043	.182	15.8	8.1
Feran 21	7.33	.267	49.0	3.6	.062	.329	54.9	11.9
Uran 32	7.26	.285	53.7	3.8	.065	.350	60.4	7.1
Cottonseed meal	5.75	.183	26.6	3.4	.044	.227	27.9	8.8
Castor pomace	6.41	.230	39.0	3.8	.060	.290	44.4	6.4
Milorganite	6.12	.174	24.2	3.1	.047	.221	26.3	8.8
L.S.D. at .05	0.74	.073	9.7	0.78	.008	.052	13.4	N.S.

TABLE 4.—COMPARISON OF SURFACE APPLIED UREA AND AMMONIUM NITRATE.*
(Condensed from Tables 1 and 2).

Crop	Treatment		Soil Type	No. of Cuttings	Net Lb. N Recovered Less Check	
	Lb. N.	Date			Urea	Ammonium Nitrate
Oats	25	Initial /30/56	Ona fs.	1	5.5	13.4
Oats	50	Initial 10/30/56	Ona fs.	1	15.0	21.9
Millet	25	Retreatment 4/6/57	Ona fs.	3	19.4	23.4
Millet	50	Retreatment 4/6/57	Ona fs.	3	54.8	77.1
Millet	50	Retreatment 7/23/57	Ona fs.	1	36.3	42.6
Oats	25	Initial 10/27/56	Klej fs.	2	5.7	11.7
Oats	50	Initial 10/27/56	Klej fs.	2	12.4	17.7
Millet	50	Retreatment 8/1/57	Klej fs.	1	26.1	28.9
Total	325				175.2	236.7
Percent Recovery					53.9%	72.8%
Oats	100	Initial 10/30/56	Ona fs.	1	33.4	32.4
Millet	100	Initial 4/6/57	Ona fs.	3	48.0	36.7
Millet	100	Retreatment 7/23/57	Ona fs.	1	68.2	71.0
Oats	100	Initial 10/27/56	Klej fs.	2	20.2	19.5
Millet	100	Retreatment 8/1/57	Klej fs.	1	59.1	75.6
Total	500				228.9	235.2
Percent Recovery					45.8%	47.0%

*Last cutting of oats on Ona fine sand omitted.
Data are averages of 4 or more replicates.

could explain the erratic results that might occur where urea is surface applied.

That loss of ammonia from materials surface applied to soils with a pH above the neutral point may be significant, has been recognized for some time (4), but the potential for loss of ammonia following surface application of urea to light sandy soils in the acid range has not been appreciated. It is well known that heavy metals such as copper inhibit the action of urease in the hydrolysis of urea (7), but practical use of copper in conjunction with urea as a specific inhibitor to retard decomposition has not been given a practical trial as yet.

Surface application of nitrogen to oats has been an accepted practice, and in the absence of this recent information was selected as the procedure to be used without including comparative tests in which urea was incorporated in the soil. The method of incorporation used in the greenhouse apparently prevented any differential volatile loss of ammonia.

SUMMARY AND CONCLUSIONS

Field plots on Ona and Klej fine sands and greenhouse plots of Lakeland fine sand were planted to oats and millet to test the relative availability of nitrogen in ammonium nitrate, urea, ureaform and certain natural organics. All nitrogenous materials except cottonseed meal were applied to the soil surface in field tests but incorporated in greenhouse tests. An overall percentage recovery in field tests showed 53.9 percent recovery from urea and 72.8 percent recovery from ammonium nitrate for 25 and 50 pound rates of nitrogen used at the various times. Percentage recoveries from the 100 pound nitrogen rates were 45.6 and 47.0 respectively. Differential recovery from the lower rates is assumed to be at least partially the result of volatile loss of ammonia from surface applied urea. This difference was not apparent in the pot studies. Differential response to the two forms of nitrogen, possibly enhanced by limited nitrification, may also have been involved.

The important contributions of the study are the greater efficiency of surface applied ammonium nitrate as compared to urea in certain of the field tests, and the relatively poor showing of the ureaform. Recovery from natural organics ranged upward from about one-half that of soluble sources under initial crops, to a somewhat higher recovery under repeated cropping. While actual measurements of volatile loss of ammonia from surface applied urea were not made in this instance, the data tends to support the findings of later work that appreciable loss of nitrogen could take place in this manner.

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Studies on the Seed-Borne Phase of Brown Spot (Pleiochaeta Setosa (Kirchn.) Hughes) in White Lupine (Lupinus Albus L.)[1]

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Brown spot (*Pleiochaeta setosa* (Kirchn.) Hughes), a serious disease of lupine in the Southeast, is favored by wet, cool weather. Lupines become infected by seed-, soil-, and air-borne inoculum (1, 2, 3). Infected seeds may be detected in white-seeded varieties by presence of tan or dark-brown discoloration. Coats of some infected seeds may be severely scarred or ruptured.

Germar (2) found that infected white lupine (*Lupinus albus* L.) seeds weighed 20 per cent less than healthy seeds. As many as 22 per cent of the plants originating from infected seeds were diseased. Treatment with Ceresan improved the rate of emergence but did not completely control seed transmission of the fungus.

During the spring of 1957 white lupine in plots at Quincy, Florida, were heavily infected with the brown spot fungus. A high percentage of seeds from these plots were discolored and scarred. Seeds without visible defects were separated from infected seeds and the latter sample was used to determine; 1) the relationship of seed discoloration to the amount of seed transmission, and 2) the practicality of disinfecting white lupine seeds with heat and the possible use of heat to eliminate the fungus from infected seeds of blue and yellow lupines.

Materials and Methods: Brown spot-infected white lupine seed (P.I. 202527) was divided into the following groups based on seed coat discoloration (Figure 1): I. Sound, very little or no discoloration. II. Slight, less than ¼ of seed coat discolored and no visible breaks or scars. III. Moderate, ¼ to ¾ of seed coat discolored and no visible breaks or scars. IV. Severe, more than ¾ of the seed coat discolored and often scarred or broken. After grading, seed stocks were stored in a refrigerator at 7 C.

The amount of seed-borne infection was determined by stand counts of diseased and healthy plants. One hundred seeds of each discoloration group were planted in methyl bromide-fumigated soil in 8-inch pots at the rate of 10 seeds per pot. Stand counts and disease ratings were made approximately 5 weeks after planting. Concurrently, 50 seeds from each dis-

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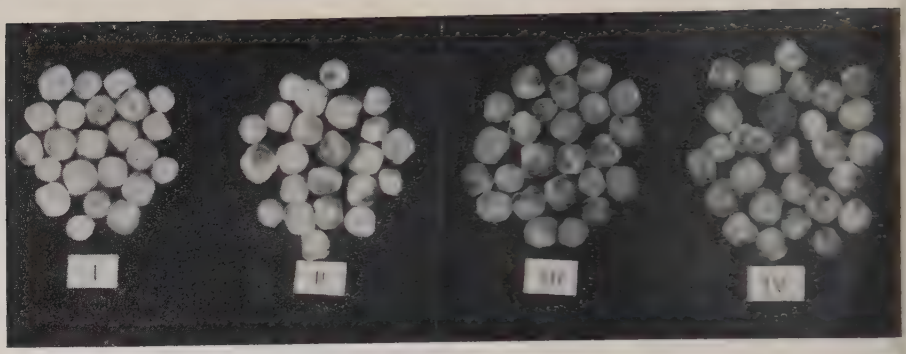

Figure 1.—*Pleiochaeta setosa*-infected white lupine seed divided into Groups I-IV on the basis of seed coat discoloration and damage.

coloration group were surface-sterilized in a solution of 20 per cent Clorox in 10 per cent ethanol for 2 to 3 minutes and then plated aseptically on potato-dextrose agar (PDA). The seeds were incubated for 1 week at room temperature and colonies of *P. setosa* that developed were counted.

To determine whether the seed-borne fungus could be killed without harming seed germination, seeds were treated in hot water and hot air. The treatment schedules were essentially those used by Weimer (4). Seeds were treated in lots of 25 or 50 enclosed in cheesecloth bags (hot-water treatments) or perforated 1-ounce ointment tins (hot-air treatments). Seeds were immersed in hot water at 50°, 51°, and 52° C. for 5, 10, and 15 minutes, with and without a 1-hour presoak treatment at 45°. The desired water temperature was maintained at ±¼° in a thermostatically controlled water bath. Hot-air treatments were conducted in thermostatically controlled incubators at 60°, 65°, 70°, and 75° ± 2° for 1, 2, 4, and 8 hours.

Unless otherwise indicated Group IV seed was used in all heat-treatment experiments. After treatment, seeds were disinfected in the Clorox-ethanol solution and plated on PDA. The effect of treatments on germination of yellow and blue lupine (*L. luteus* L. and *L. angustifolius* L., respectively) was measured in some experiments because of insufficient healthy white lupine seed.

Results and Discussion: The extents of seed-borne infection in different groups of seed are shown in Table 1. The more severely discolored seed yielded smaller stands and a higher percentage of infected plants. The apparent anomaly in Group I (Sound seed), where lower stand counts and a slightly higher disease incidence occurred than in Group II (Slightly discolored seed), may be explained by the fact that few sound seeds were left in the culled lot after the initial separation. The clean, white seeds or those with only slight discoloration were usually small and thin and produced at best, small spindly plants.

It was consistently observed that 65 to 75 per cent of Group IV seeds yielded the fungus. Although fewer than 1/3 of the plants originating from such seed were visibly diseased it is believed that the fungus in or on infected seed contaminates the soil, persists saprophytically, and infects current or succeeding lupine crops.

Results of 2 experiments on efficacy of hot-water treatments are summarized in Table 2.

These data suggest that *P. setosa* can be eradicated from seed by hot-

TABLE 1.—PER CENT OF *P. setosa*-INFECTED WHITE LUPINE SEEDS IN EACH GROUP AND ITS EFFECT ON STAND AND SEED TRANSMISSION OF *P. setosa*.

Group	Infected Seed	Stand	Seed Transmission
	%	%	%
I	4	84	2
II	14	91	1
III	32	87	5
IV	66	61	20

water treatment. They also suggest that the procedure could be modified to eliminate, in part, the prolonged soaking and resultant seed damage. Germination of yellow lupine seed was more adversely affected by hot-water treatment than that of blue lupine. Germination of blue lupine seed did not decline appreciably except after presoaking and treatment at 52°C for 10 and 15 minutes. Weimer (4) found that presoaking and treatment at 50 reduced germination from 98 per cent for a 5-minute treatment to 76 per cent for a 10-minute one, and 68 per cent for a 15-minute one. He did not test yellow lupine seed.

Although hot-water treatment was effective it is not commercially desirable. However, it may be useful for treating small lots of valuable breeder's seed.

Data presented in Tables 3 and 4 suggest that the effectiveness of hot-air treatment is influenced by the moisture content of the seed at the time of treatment. Group IV stocks sampled during the 6-month period after harvest were thoroughly disinfected by 2 to 8-hour hot-air treatments at 75 C (Table 3); less than 6 per cent reduction in the germination of blue and yellow lupine controls occurred. However, after a lapse of about 1 year from the first tests the bulk lot was retested 3 times. (Depletion of Group IV seed necessitated bulking the remaining seed groups.) The 60 and 65 treatments were eliminated because of their ineffectiveness. Results presented in Table 4 are typical of all 3 tests.

TABLE 2.—EFFECT OF HOT-WATER TREATMENT ON PER CENT INFECTION OF GROUP IV WHITE LUPINE SEED DISCOLORED BY *P. setosa* AND ON GERMINATION OF BLUE AND YELLOW LUPINE CONTROLS.

Time and temperature	One hour presoak at 45°C			No presoak treatment		
	Infected	Germination		Infected	Germination	
	White	Blue	Yellow	White	Blue	Yellow
	%	%	%	%	%	%
50°C, 5 min.	0	95	74	22	97	82
50°C, 10 min.	0	96	74	10	99	82
50°C, 15 min.	0	92	69	8	99	79
51°C, 5 min	0	95	72	12	98	80
51°C, 10 min.	0	95	72	5	98	80
51°C, 15 min.	0	92	58	7	99	68
52°C, 5 min.	0	93	69	11	97	74
52°C, 10 min.	0	89	63	10	99	68
52°C, 15 min.	0	87	51	0	97	66
Presoak only	2	96	77			
Untreated Checks	64	97	68			

TABLE 3.—EFFECT OF HOT-AIR TREATMENT ON THE PER CENT *P. setosa*-INFECTED GROUP IV WHITE LUPINE SEED SAMPLED 6 MONTHS AFTER HARVEST.

Time in hours	60°C	65°C	70°	75°C
	%	%	%	%
0	60	—	—	—
1	72	72	52	16
2	60	48	32	0
4	64	72	16	0
8	76	60	0	0

Apparently seed desiccation under refrigerated storage increased tolerance of *P. setosa* to hot-air treatment. With no artificial drying following harvest, seed probably averaged 13 to 15 per cent moisture content. After 1 year's storage at 7 C, the moisture content measured 10.5 per cent. Data in Table 4 suggest that a longer treatment at 75 . or treatment at a higher temperature may eradicate the fungus even at reduced moisture contents.

TABLE 4.—EFFECT OF HOT-AIR TREATMENT ON THE PER CENT *P. setosa*-INFECTED WHITE LUPINE SEED SAMPLED AFTER 1 YEAR'S REFRIGERATED STORAGE.

Time in hours	70°C	75°C
	%	%
0	32	—
1	34	28
2	34	22
4	18	18
8	20	14

Even though the effectiveness of hot-air treatment is apparently governed by factors including length of treatment, temperature, and moisture content, it is believed suitable schedules for such treatments can be established. Crop driers used in Florida can accommodate the increased temperature necessary to eliminate *P. setosa* from seed. Weimer (4) found treatments used in this study to be effective in eliminating the anthracnose fungus (*Glomerella cingulata* (Ston.) Spaul. & Schrenck) from blue lupine seed. Therefore, a measure potentially capable of eliminating 2 important pathogens from infected lupine seed merits further investigation.

Summary: White lupine seed harvested from plots heavily infected by *P. setosa* was divided into 4 groups based on the extent of seed coat discoloration. Infection ranged from 4 per cent in Group I (Sound seed) to 66 per cent in Group IV (Severe discoloration). Disease transmission in seed ranged from 2 per cent in Group I to 20 per cent in Group IV.

Hot-water treatments of 5 to 15 minutes' duration at 50 C, preceded by a presoak treatment at 45 for 1 hour, completely eliminated the pathogen. Germination of similarly treated blue or yellow lupine seed was not reduced.

Hot-air treatment at 75 C for 2 to 8 hours was also effective in seed

disinfected shortly after harvest. However, after 1 year's storage at 7 the fungus was no longer completely eradicated by treatment at 75 for 2 to 8 hours.

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Blackheart of Chicory[1]

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Blackheart of chicory, *Cichorium endivia* Linn., a physiological disorder, occurs in commercial fields of chicory, or Green Curled Endive, principally in the late spring and early fall, but is not a problem during the winter season. The first symptoms appear as unnatural curling of the younger leaves, followed by a blackening of the tips of these heart leaves. As the head continues to grow, these younger leaves move towards the outer edge of the plant while new leaves form at the center. In severe cases the blackhearting continues until the whole head is affected. No primary fungus or other disease organisms have been found to be the cause of this breakdown. Sap-feeding beetles and other insects are often present in more advanced cases of blackheart, but here again these are secondary organisms attracted by decaying vegetative matter.

Chicory is grown commercially in central Florida both on sand in the Sanford area and on peat in the Zellwood area. This crop is used mainly as salad greens, taking the place of, or mixed with, lettuce. Some chicory fields may show as high as 95 per cent blackheart, necessitating disking under the whole crop, whereas other fields may show less than one per cent blackheart at the same date.

METHODS AND RESULTS

A *winter* crop of chicory on peat at Zellwood was seeded October 3, 1958. The fertilizer levels consisted of 0, 1, 3, and 5 tons per acre of 5-5-8 fertilizer, each level being replicated six times. One half of the fertilizer was applied at the time of planting, and the second half was applied as sidedressing November 5, 1958. Composite 0-6" soil samples from all fertilizer treatment plots were taken once a month. These samples were analyzed for soluble salts in the soil, Table 1.

There was no blackheart of chicory noted at any of these fertilizer levels during this winter growing season, nor in two previous winter crops.

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TABLE 1.—SOLUBLE SALTS IN SOIL (0-6") AT DIFFERENT SAMPLING DATES.

Fertilizer Levels	Soluble salts*					
	10/3/58	11/5/58	12/9/58	1/6/59	2/10/59	3/5/59
0 T/A	76	18	29	13	22	15
1 T/A	Pre-fertilizing	20	43	17	28	22
3 T/A	mean	22	78	26	74	28
5 T/A		32	101	24	74	55

*Solubridge readings in mhos x 10^{-5}

A *spring* crop of chicory was planted April 8, 1959 on the same fertility level plots at Zellwood which had been used for the winter crop. The same fertilizer levels used in the winter crop, namely 0, 1, 3, and 5 tons per acre of 5-5-8 fertilizer, were set up for the spring crop. Composite soil samples (0-6") were collected during the spring season and analyzed for soluble salts as shown in Table 2.

Thus, there was a marked increase in both soluble salts in the soil (0-6") and in blackheart of chicory at the higher fertility levels during the spring of 1959.

Calcium chloride ($CaCl_2$) and sodium chloride (NaCl) at the rate of five pounds per 100 gallons of water were sprinkled separately on different replicated plots of all fertility levels of the experiment June 2, 1959. One gallon of solution was applied to twelve feet of row as a foliar drench. By June 11, 1959, there was noticeable scorching of the chicory leaves (distinct from blackheart symptoms) where both calcium chloride and sodium chloride were applied. On the same date, plots receiving 5 tons per acre of fertilizer and treated with calcium chloride showed 36 per cent of the plants blackhearted, while at the same fertility level, plots treated with sodium chloride had 85 per cent of the plants showing blackheart symptoms.

On June 11, 1959, the same plots were again sprinkled with solutions of calcium chloride and sodium chloride, but the concentration of each chemical was reduced to 2.5 pounds per 100 gallons of water to avoid burning the foliage. At this reduced dosage no burning occurred and the same reaction by the chicory plants to calcium chloride and sodium chloride was observed as described for the higher dosage rates of the two salts.

TABLE 2.—RELATIONSHIP BETWEEN SOLUBLE SALTS IN SOIL (0-6") AND BLACKHEART OF CHICORY.

Fertilizer Levels	Soluble salts*						Blackheart per cent
	4/8/59	5/5/59	5/15/59	6/2/59	6/11/59	6/24/59	6/2/59
0 T/A	28	27	30	33	33	30	26
1 T/A	20	60	43	62	50	45	29
3 T/A	28	110	110	136	102	83	61
5 T/A	20	150	145	196	170	100	57

*Solubridge readings in mhos x 10^{-5}
(1 vol. soil: 2 vol. distilled water)

TABLE 3.—SOIL ANALYSES FROM CHICORY PLOTS SAMPLED FEBRUARY 2, 1959.*

Fertilizer levels (5-5-8)	Pounds of available nutrients per acre (0-6")				
	pH	CaO	MgO	P_2O_5	K_2O
T/A	6.3	5596+	2633	85	311
T/A	6.3	5596+	2633	116	475
T/A	6.0	5596+	2540	150+	723+
T/A	5.9	5596+	2633	150+	723+

*Analyzed by Dr. Herman L. Breland, Assistant Soils Chemist, Department of Soils, Gainesville.

Composite soil samples (0-6") collected from these chicory plots on February 9, 1959, between the winter and spring crops were analyzed for available nutrients. (Table 3).

These data reflect the high levels of available nutrients present at this time.

A *fall* crop of chicory was planted on peat at Zellwood August 25, 1959. Five fertilizer levels, 0, ½, 1, 3, and 5 tons per acre of 5-5-8 fertilizer were applied, each replicated five times. Half of the fertilizer was applied August 25, 1959, and the remaining half September 29, 1959. The 5 T/A plots were given an additional 2.5 T/A of 5-5-8 fertilizer October 20, 1959 in order to guarantee a soil condition favorable for inducing blackheart symptoms.

Soluble salts were determined for composite soil samples (0-6") collected from these new plots on peat during the fall of 1959. The results of these analyses are given in Table 4.

TABLE 4.—SOLUBLE SALTS IN SOIL (0-6") AT DIFFERENT SAMPLING DATES—FALL 1959

Fertilizer levels (5-5-8)	Soluble salts (mhos x 10^{-5})							
	8/25/59	9/9/59	9/29/59	10/13/59	10/20/59	11/3/59	11/10/59	11/17/59
0 T/A	26	22	18	20	20	22	22	30
½ T/A	28	28	18	32	32	32	26	35
1 T/A	28	40	22	34	38	38	32	35
3 T/A	26	80	34	85	85	75	80	76
5 T/A	28	95	50	100	110	190	170	175

On October 22, 1959, an application of 1000 pounds of hydrated lime per acre was applied to the soil on one third of all fertilized plots. At the same time a solution of 2.5 pounds of calcium chloride per 100 gallons of water was applied with a sprinkling can to another third of the plots, leaving one third of all plots as untreated checks. The calcium chloride treatment was repeated at weekly intervals for a total of three applications at the rate of one gallon of solution per twelve feet of row per application.

On November 17, 1959, soil samples were collected, blackheart counts made, and chicory harvested from these plots. The data are summarized in Table 5. All figures are averages for five replicates.

These data from the 1959 fall crop of chicory show a marked increase in blackheart with increasing levels of fertility in the untreated and lime

TABLE 5.—DATA FOR CHICORY PLOTS HARVESTED NOVEMBER 17, 1959.

Fertilizer levels (5-5-8)	Soluble salts (mhosx10^{-5})	Av. wt. per head (Lbs.)	Per cent blackheart		
			Checks	Lime (soil)	$CaCl_2$ (foliar)
0 T/A	30	1.0	0	3	0
½ T/A	35	1.2	0	3	0
1 T/A	35	1.3	6	6	0
3 T/A	76	1.6	29	21	0
5 T/A	175	1.8	63	43	0

treated plots. There was an increase in average weight per head of chicory with increasing amounts of complete fertilizer (5-5-8). While there was only a slight reduction in blackheart of chicory by the addition of hydrated lime to the soil after blackheart was present, there was a complete elimination of blackheart by three weekly drenches of calcium chloride at the rate of 2.5 pounds per 100 gallons of water.

Leaf analyses of chicory from high and low fertility plots showed less calcium in the plants affected by blackheart than plants not affected by blackheart. For example, non-blackhearted plants from the plots which did not receive fertilizer analyzed 1.15 per cent Ca against only 0.70 per cent Ca for blackhearted plants from the 5 T A level of fertilizer application. Leaf samples for these analyses were collected from the unsprayed check rows.

Blackheart has been observed both in chicory and escarolle grown on peat and sand. Experimental plots of chicory on sand at Sanford grown during the fall of 1959 showed blackheart at the higher fertility levels.

DISCUSSION

Blackheart symptoms in celery have long been associated with high soluble salts in the soil (2, 3, 7, 8). The addition of soluble calcium in the soil (8) and the more efficient soluble calcium foliar sprays (3) have been used more recently to correct blackheart of celery by furnishing available calcium to the heart of the plant.

Blackheart of celery, blossom-end rot of tomatoes, and blackheart of lettuce have been pictured as due to calcium deficiencies (6). Tissue anaysses have shown blackhearted celery to be lower in calcium than normal tissue. (9, 3). Blossom-end rot of tomatoes and peppers have been corrected by the addition of foliar calcium sprays (4,5).

Blackheart of chicory, which appears on peat during the early fall and late spring when nitrification and soluble salts are high, follows a pattern similar to these other vegetables, being most prevalent in the presence of high soluble salts in the soil. The addition of calcium sprays to the chicory foliage corrects the blackheart by supplying available calcium directly to the growing bud.

SUMMARY

Blackheart of chicory, *Cichorium endivia* Linn., a physiological disorder, occurs in commercial fields of chicory, or Green Curled Endive, principally in the late spring and early fall, but is not a problem during

the winter growing season. The first symptoms are a curling of the younger leaves in the center of the head, followed by a blackening of the tips of these heart leaves caused by a deficiency of calcium in the growing bud.

At the higher fertility levels the incidence of blackheart was much higher than at lower levels in spring and fall crops. No blackheart was observed at any fertility level during winter crops. There was only a slight reduction in blackheart when lime was applied to the soil, but a complete elimination of blackheart occurred when calcium chloride at the rate of 2.5 pounds per 100 gallons of water was drenched on the foliage once a week for three consecutive weeks.

These results with blackheart of chicory are similar to results obtained with other crops, such as celery, tomatoes, and peppers, where a calcium deficiency brought about by high soluble salts in the soil can be corrected by the addition of foliar applications of calcium solutions.

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John Clayton Gifford (1870-1949), and the Florida Everglades

GEOFFREY J. MARTIN[1]

Ten years have passed since the death of John Gifford, and both the man and his life's work have been largely forgotten. It is the purpose of this brief paper to remind ourselves that Gifford contributed a great deal towards an understanding of the Everglades region of Florida, to outline his provocative suggestions, feelings and ideas, and to stimulate interested persons to re-evaluate his work.

Gifford, born in 1870, was formally educated at the University of Michigan, Johns Hopkins and Munich, Germany; at this latter institution he received the degree, Doctor of Economics. Between 1895 and 1896 he experienced considerable work in the field as a forester with the New Jersey Geological Survey; later he lectured forestry at New York State College, worked with the Bureau of Forestry, the United States Department of Agriculture, founded "*The Forester*," which is now known under the title of "*American Forests and Forest Life*," wrote books and articles, and passed many of his years as Professor of tropical forestry at the University of Miami.

It was early in the century, when Gifford came to the University of Miami, that his interests focused upon South Florida. His formidable academic training, practical experience, belief in the inevitability of human progress, and deep understanding of nature's delicate balance in the Everglades were passed on to many spectators in the form of publications, public lectures and classroom teachings.

And so it was that Gifford distributed understanding to many uninformed people in the early years of Everglades reclamation. This was valuable support to a project lacking substantially in funds and public enthusiasm. Gifford alone formed the academic support for the forceful Governor Napoleon Broward who had conjured dreams of an Everglades "Economic Empire"; Broward, of early twentieth century fame, was progressive and determined to develop South Florida, but could only answer the unbelievers of Okeechobeeland by claiming that drainage would solve all problems since "water runs down hill." Satisfactory though this explanation may have been from the political platform, it was certainly disquieting to many of the better informed Floridians in their more thoughtful moments. It was therefore of great value to Broward's reclamation scheme when Gifford's optimistic voice was heard expressing itself in this crucially formative hour in *Conservation*, *Forestry and Irrigation*, *Garden Magazine*, *Everglade Magazine*, *Southland Magazine* and elsewhere. Indeed, by 1911 so impressed was the Everglade Land Sales Company with Gifford's academic proof and optimism that it published a collection of his essays concerning the potential value of the Everglades. It was a beginning; Everglades, for long the domain of Indian and wilderness, was now to be interviewed seriously by the white man with a view to employment.

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Gifford was a much traveled man and a believer in the value of this experience. It occurred to him that studies of the problems and difficulties of satisfactorily reclaimed areas of other world regions would be of great value to reclaimers in the Everglades. Thus it was that Gifford came to study the Landes area of France, the polders of the Netherlands, the heathland of Denmark and the Fenlands of England. He stated that the success of these schemes across the Atlantic insured the practicability of similar undertakings in the Everglades, and that first hand experience of these matters should be derived by importing the very men who were responsible for the reclamation and maintenance of the relevant areas in France, the Netherlands, Denmark and England. Was it then to be wondered at when Gifford compared Governor Broward to Dalgas of Denmark, and Bremontier and Chambrelent of France? Although Gifford was guilty of a fundamental error in reckoning on a transfer of problems and experiences from a West European climate to a sub-tropical climate, one nevertheless feels that his desire for comparative studies between areas possessing basically similar structural problems is a significant contribution whose full value has not been exploited in South Florida.

So impressed was Gifford with his approach of understanding through comparison, that he applied his findings of tree and crop production in the West Indies to the Everglades, which share a not dissimilar geographic location and climate. The warm trade winds reach the Everglades from the West Indies, so that climatically and botanically South Florida is very similar to Cuba and the Bahamas, though a little cooler in winter which in any case induces quality in fruit. He then proceeded to demonstrate that Floridians could establish tree stands of economic significance, and develop ground crops of great worth, including the papaw, banana, lime, sapodilla, mango and sugar cane. This sub-tropical harvest could be gathered and shipped to a wintered, desolate, and snow ridden north to cater to an insatiable demand. Gifford utilized this producer-consumer relationship in the development of one of the earliest benefit cost ratios that was attempted for the Everglades. "I have called this the greatest conservation project in the United States because at the cost of about one dollar, an acre of land capable of producing net two hundred dollars' worth of vegetables annually is actually formed out of the useless mud sloughs." Clearly his benefit cost ration was inaccurate, but this does not detract from his performance as a pioneer in this work.

Gifford believed, as did Broward, that drainage of the Everglades would insure reclamation and in this respect he, together with his most advanced contemporaries, underestimated the complexity of reclaiming the land in this part of Florida. Nevertheless, Gifford insisted that since an artificial drainage pattern had been established by man a continuation of this reclamation process would be insured by the use of nature's own pumping device—the tree. As Gifford says in an article "Trees as an aid to drainage" in *La Hacienda*, "Some trees transpire more than others, and, of course, in a climate of continuous summer, transpiration throughout the year is enormous. Rapidity of growth is determined by the amount of moisture available. The amount transpired depends upon the supply of water, the rate of growth and the condition of the atmosphere. Given then a wet soil, a fast growing tree, such as a cedrella or eucalyptus or any one of a hundred or more fast growing tropical trees, with a dry, windy atmosphere, and you will have a pump working quietly and constantly that would rival a windmill." Gifford continues and introduces again his desire to

understand through comparison. "I have heard it said that in India eucalyptus trees were planted along an irrigation ditch. These robbed the ditch of so much water that they were cut down. The region around San Paulo delle Tre Fontane, it is claimed, was drained and rid of pestilential fevers by the planting of eucalyptus. Along the Mediterranean shore I have found the belief prevalent that eucalyptus plantations keep off fever." Every tree is an efficient pump which never needs repairs or fuel for power. Trees consolidate the soil by their roots, add to the fertility by their decomposing leaves and furnish roosting places for water birds that enrich the soil. More recent studies concerning transpiration rates of trees in South Florida certainly indicate that Gifford's ideas were substantially correct. As a forester he was quick to realize the impossibility of growing certain types of tree in the Everglades, where an exceedingly high water table prevailed, and so he compiled a list of such trees that would flourish in this low lying region that was subject to floods: the bamboo, the royal and coco palm, Australian pine or beefwood, several native trees belonging to the eucalyptus family such as the rose apple, cuban cedar, Florida buttonwood, sapodilla, mastic, princewood and mahogany. Many of these trees recommended by Gifford have considerable economic value as hardwood, softwood, ornamentation, windbreak, fuel and medicine. It is not without significance that J. H. Davis, in the Florida Geological Survey Bulletin 25 states, "Forestry on a large scale has not been practiced in the Everglades, but as pointed out by Gifford, many trees might prove well adapted to some Everglades conditions and their growth on a large scale could be promoted."

Gifford, too, shared the vision of an Everglades National Park with other Floridians as early as the 1920's, although probably the first direct quotation available from his writings is dated 1934, "Over on the mainland in the region of Cape Sable is the territory destined in time to be a National Park. This area will in due course come under the control of the National Park Service. Its future care and development will be assured when this branch of our government accepts title." He traveled the area that was later to become the Everglades National Park, making known his belief that "here is one piece of land about which there could be no controversy . . . . It is fit simply to marvel over . . . It is natural, unaffected by man's interference, one of the few places on earth that we can hand to posterity without mutilation if we hurry in the process of preservation." Gifford's pleas were heard and noted by politicians who had come to respect his learned opinion and judgment; it was in this way that the man played a not insignificant role in the establishment of the Everglades National Park in 1947.

In his later years as a faculty member at the University of Miami, Gifford became deeply impressed with the growth, development and potential of the State of Florida. He appreciated that a happy future belonged to Florida and that development of the Everglades would need to be undertaken scientifically, using the best equipment, men, ideas and plans available: in furtherance of this necessary work he asserted that the University of Miami, perched on the very rim of the Everglades, should become the research headquarters for talented academic investigation into the numerous problems of conservation. The Everglades would serve as an admirable laboratory. There are certain unassailable advantages in this plan but unfortunately, owing largely to lack of funds, it has never been brought to fruition. Today the University of Miami does have a Bureau

of Economic Research which has sponsored some research pertaining to the Everglades, but it is not the Everglades academic center of which Gifford dreamed.

Clearly Gifford's contribution toward an understanding of the Everglades region of Florida has not been without significance, and it is surely deserving of more attention. The ideas outlined above, incomplete and briefly described, are but a minute part of John Gifford's total contribution. It is the author's hope that this paper will prompt a more thorough inquiry by those who knew the man and his ideas intimately, for this greater diversity will benefit our endeavors in the Florida Everglades.

Interaction of Water and Gamma Irradiation on Seedling Vigor in Oats[1]

Alvin T. Wallace[2]

Among evolutionists it is generally held that the genetic constitution of a species has evolved to the point of functioning as a balanced system. Any mutation occurring in such a system generally throws the system out of balance, reducing its efficiency; most artificially induced mutations would also be expected to be harmful to the efficiency of the organism. From research results indicating this truth, it may be deduced that most of the so-called "beneficial mutations" are those that are beneficial to mankind and not necessarily to the organism.

Mutations initially harmful to the organism, however, may with time become beneficial to the organism if sufficient modifying genes are accumulated to buffer the mutations' harmful effects or if the organism which carries the mutation is moved to a different environment in which the mutation could become beneficial. Mutations are usually recessive and could be carried along in heterozygous condition in a cross-pollinating species until sufficient modifying genes are accumulated to buffer their effects from harmful to beneficial. Because self-pollinating species reach homozygosity very quickly upon selfing, any harmful recessive mutations would be eliminated before modifying genes could be accumulated in the individual carrying the mutation. Thus, one would expect that a mutation breeding program would be more successful with a cross-pollinating species than with a self-pollinating species, assuming equal genetic variance present at the start of the program.

Evolutionists usually agree that selfing, evolutionarily speaking, rapidly leads up a blind alley, and self-pollinating species are thought to evolve mainly by interspecific crossing. Yet, it is well known that self-pollinating varieties, oats, for example, tend to become more variable after they are released, although of course, this can occur by accident through outcrossing and seed mixtures. But they can also become more variable by the accumulation of mutations in the homozygous state. Since mutations are usually harmful, they would not be expected to be accumulated unless

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the self-pollinating species has the capacity to absorb them. This type of reasoning has led Gregory (18) to propose that, in order for mutations to have a significant effect on production of varieties and adaptability in self-pollinating species, they must either then be less deleterious on the average than in the cross-pollinating species or be subject to immediate and successful modifications. Since there is no evidence that self-pollinating species can modify the mutations *per se* once they have occurred, Gregory further proposes that self-pollinating species have an internal mechanism for making the mutation, once it has occurred, less harmful to the self-pollinating species. Thus, one may say that self-pollinating species have a greater buffering capacity than do cross pollinating species against harmful effects of mutations.

This hypothesis leads one to assume that the use of irradiation in plant breeding with self-pollinating species has much more merit than once thought.

If mutation breeding is to be a part of the general plant breeding program with self-pollinating species, then a major question arises: what is the best procedure for obtaining the highest frequency of mutations in self-pollinating species with the lowest frequency of chromosome aberrations? Conger (9) states that the problem is not only to induce mutations, but to have survival of the induced mutations. To be useful to plant breeders, mutations must be (1) heritable, (2) viable, and (3) must exist frequently enough to be selected by the screening process. A great deal of research has been reported on the mutation rate in *Drosophila*, mice, and microorganisms.. In *Drosophila* (2) this rate varies from 1.6×10^{-8} to 5.7×10^{-5} per roentgen per locus. For mice (30) this rate may be up as high as 25×10^{-5} per roentgen per locus. Very little is known about the induced mutation rate at a specific locus in higher plants. Stadler (32, 33) has reported on the spontaneous mutation rate at a locus in corn, but no other work of this nature has been reported. Lack of information on mutation rate at specific loci in higher plants stems from the almost prohibitive amount of time and expense involved in collecting such information. Heretofore, all information about mutation rates at specific loci in higher plants has been obtained by extrapolation from that obtained with other organisms. No information is available to support or reject the validity of such extrapolations.

Recently, a technique has been developed by Wheeler and Luke (35) which can be used to screen large numbers of individual oat plants for mutations at a specific locus controlling resistance to a fungus *Helminthosporium victoriae*. This technique allows the determination of mutation rate in higher plants.

The writer has initiated a program using the Wheeler and Luke technique to obtain information on the mutation rate at a specific locus in oats. The basic assumption is that mutation rate increases with ionization dose. This implies that the more radiation a plant can receive, yet still remain viable, the higher the frequency of mutation.

The above assumption is supported by a large amount of research data (21, 24, 25, 26, 27).

The problem thus became one of finding modifying agents that would reduce the radiosensitivity of the plant without decreasing the induced mutation rate.

Numerous biological and physical factors are known to influence the radiosensitivity of plants to sparsely ionizing radiations. Studies designed

to determine the radiosensitivity of plants and seed have, to a large degree, used seedling height, chromosome aberrations, and chlorophyll deficiencies as the criteria. Nilan (27) in a review lists genotype, stage of cellular development, age of tissue, chromosome number and size, moisture, temperature, atmosphere, storage after irradiation, and certain chemicals as some of the more important factors influencing a plant's radiosensitivity.

This report is concerned with the modifying effects of seed moisture content. At present only seed have been irradiated. Since plants must be grown for two generations following seed irradiation to determine the mutation rate, the preliminary testing of the sensitivity of seed with different moisture contents is being conducted by measuring seedling heights of the treated seed. The particular treatments that most reduce radiosensitivity will then be used in screening for mutation rate.

REVIEW OF LITERATURE ON SEED MOISTURE CONTENT AND RADIOSENSITIVITY

In a review of research on mechanisms of radiation protection, Patt (28) states that Petry (29) reported in 1922 that hydration increased the radiosensitivity of seeds. Between that date and 1954, a good deal of research (7, 8, 11, 19, 20) showed that seeds with high moisture content were the most sensitive to sparsely ionizing radiations. For example, Gelin (17) reported that barley seeds which had been soaked for 23 hours and then x-rayed showed 50% chromosome aberrations, whereas those with 10% moisture receiving the same x-ray dose showed only 13% chromosome aberrations. Of course, it is well known now that after 23 hours of soaking at room temperature, the cells in barley embryos would be approaching metaphase. Ehrenberg, *et al* (15) reported that barley seeds soaked for 24 hours and given very low x-ray doses produced six times the frequency of chlorophyll deficiencies as that of dry seeds.

In 1954 Ehrenberg *et al* (16) and Ehrenberg (12) in Sweden and Caldecott (36) in the U. S. reported that dry seeds were more sensitive than moist seeds. Caldecott (36) reported an inverse relationship between moisture content of seeds and their radiosensitivity, provided the metabolic activity was not changed during hydration. These results changed the viewpoints on moisture effects and stimulated a series of experiments testing the interaction of seed moisture content and radiosensitivity. In 1955 Caldecott (4, 5, 6) and Ehrenberg (13, 14) published a series of papers supporting the inverse relationship at moisture levels of seeds below 8%. Seeds appear not to vary in sensitivity at moisture contents above 8%. All of Caldecott's and Ehrenberg's research was conducted with barley. In 1957 Abrams and Frey (1) reported that oats were more resistant to x-ray damage at 13.8% moisture than at 5 or 18%. They also reported that the sensitivity of oat seed at 5% moisture seemed to be independent of dose.

These results along with other evidence led Swanson *et al* (34) to propose that the sensitivity of the chromosomes to irradiation is in relation to their water content. Chromosomes are hydrophilic gels which can absorb or release water. They are more sensitive to radiation when dehydrated. To further support his view, Swanson quotes Sparrow's (31) results showing that there is a progressive increase in the frequency of chromosome aberrations by x-rays as cell division proceeds, with the metaphase chrosomes being the most fragile. Although Swanson did not specifically limit his proposal to sparsely ionizing radiations, a number

of workers (5, 22, 23, 24) have shown that heavy ionizing radiations results on seeds seem to be independent of moisture.

Recently a report by Curtis *et al* (10) shows that if barley seeds of 4% and 8% moisture are stored after x-ray irradiation, storage increased the damage to the 4% seed by a factor of 20 while it increased damage to the 8% seed by a factor of only 5. On the other hand, when the 4% seed were hydrated immediately after irradiation, they showed no more x-ray damage than the 8% seeds. Neutron damage was independent of storage and or hydration.

METHOD OF PROCEDURE

The variety Victorgrain oats was used. Seeds of various moisture contents were irradiated with cobalt-60 gamma rays at doses from 10 to 80 kilo roentgens. The seeds were grown on moist blotters in 4" x 4" plastic cartons placed in a growth room (72±3 F) and the seedling heights measured after 8 to 10 days. Fifty seed were placed in each carton, and each treatment was replicated 4 times, for a total of 200 seed per treatment.

RESULTS

A number of tests were conducted in which the seed were adjusted to different moisture contents by bringing them to equilibrum over different dehydrating agents before irradiation. The results of five such tests are presented in Table 1, which show seedling heights of the various treatments presented as a percent of the non-irradiated controls. The results from each test will be discussed separately.

TABLE 1.—SEEDLING HEIGHT OF OATS 8 TO 10 DAYS OLD AS A PERCENT OF CONTROLS.

Test No.	Seed Moisture	Irradiation treatment in kilo-roentgens								
		0	10	20	30	40	50	60	70	80
1	3.7%	100	48.0	40.3	14.3	8.1	4.5	3.6	0.3	0.0
	7.5%	100	....	50.2	....	23.7	23.5	18.0	11.9	....
	10.3%	100	93.3	77.2	45.3	35.9	21.0	10.2	3.9	1.5
2	5.9%	100	88.2	61.9	28.4	16.0	7.1	2.1	1.7	0.5
	11.1%	100	96.5	87.9	64.9	42.0	31.2	17.7	6.9	3.0
	26.0%	100	77.3	37.7	24.6	6.9	1.2	0.3	0.0	0.0
3	7.7%	100	85.9	61.7	51.6	42.2	30.5	22.7	15.6	13.3
	9.6%	100	86.3	83.9	79.8	57.2	44.4	37.9	27.4	21.0
	1)7.7%	100	69.8	45.6	28.4	26.8	14.0	13.0	8.7	7.9
	1)9.6%	100	91.8	87.8	70.0	42.0	25.9	13.8	11.3	11.1
4	2)3.2%	100	56.8	46.0	47.5	26.6	24.3	23.4	17.7	0.0
	2)5.3%	100	59.6	37.5	49.0	34.6	18.7	16.2	15.4	11.0
	2)12.5%	100	93.0	75.4	61.6	45.5	21.9	15.3	12.6	10.6
	3)3.2%	100	71.5	87.5	51.9	25.3	25.9	16.3	20.5	0.0
	3)5.3%	100	4)42.1	4)41.7	53.5	33.9	19.6	12.8	14.1	9.3
	3)12.5%	100	96.7	94.2	75.6	34.1	22.8	17.2	11.6	9.9
5	3)6.8%	100	80.6	81.9	68.7	47.1	30.6	16.6	16.3	10.1
	3)9.6%	100	94.6	81.7	45.8	43.0	25.0	16.6	13.5	11.7

1)Low intensity.
2)Stored for 24 hours before planting.
3)Wet immediately under vacuum.
4)These two treatments missed at one watering.

Test Number 1—This test had three lots of seed adjusted to 3.7, 7.5 and 10.3% moisture content. It is obvious from Figure 1, which represents the data from this test, that the seed with 3.7% moisture were more sensitive to radiation than the seed with 10.3% moisture. The seed with 7.5% moisture were intermediate in sensitivity.

Test Number 2—To further test moisture effects on sensitivity, seed with 5.9, 11.1, and 26.0% moisture contents were irradiated. Figure 2 presents the results from this test. Here again the seeds with low moisture content were still more sensitive than the 11.1% seed. Also, the seed with 26% were still more sensitive than even the 5.9% seed. This increased moisture content was obtained by soaking them for 1 hour in heavily iced water prior to irradiation. The metabolic rate may have increased slightly during this period but not enough to account entirely for the increased sensitivity.

Test Number 3—This test was different from the two previous ones. Seed were equilibrated to 9.6% and 7.7% moisture and then samples of each were irradiated at a high intensity of 4200 roentgens per minute for

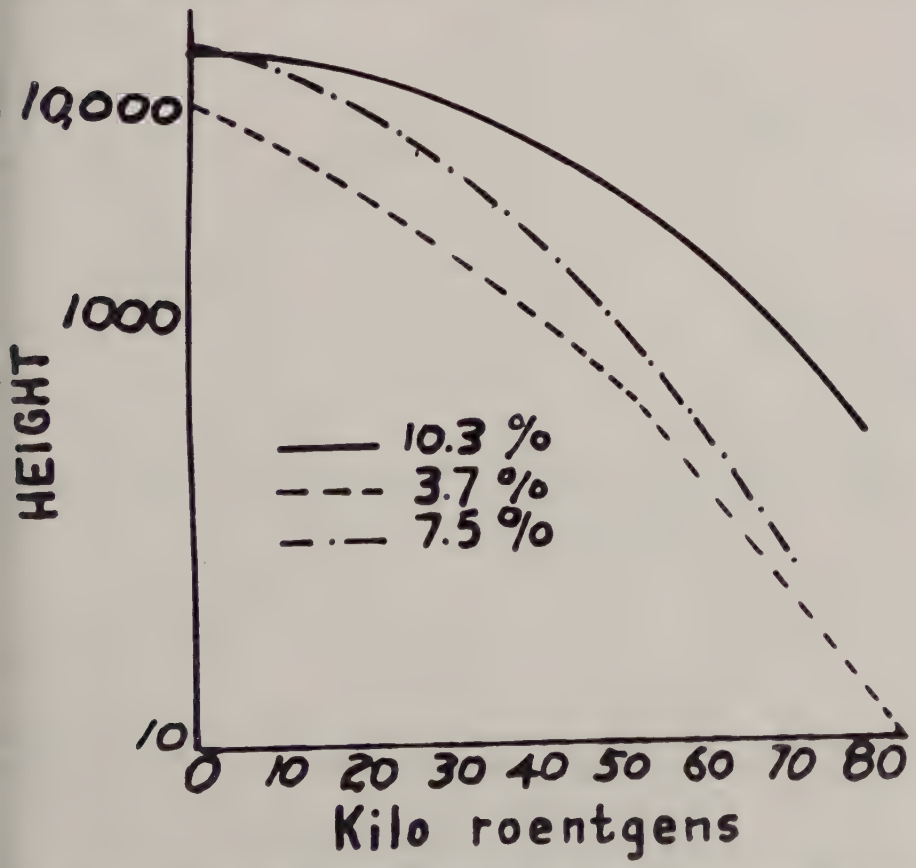

Figure 1.—Log of total height of seedlings in mm grown from irradiated oat seed having 10.3, 3.7, and 7.5% moisture content and receiving doses of gamma rays from 0 to 80 kiloroentgens.

different dosages and at low intensities for the same dosages. The low intensities ranged from 2 to 16 roentgens per minute. After irradiation, both sets of seed were planted at the same time within a few minutes after the high intensity radiation was completed. The ratio of seedling heights are presented in Figure 3. The ratio is the percent that the seedling heights of the 7.7% seed are of the 9.6% seed. As can be seen in Table 1 and Figure 3, when compared to the 9.6% seed, the seed with 7.7% moisture were damaged much more at low irradiation intensities than at high intensities. The probable reason for this increased damage to the 7.7% seed is the effects of storage. Curtis *et al* (10) reported that barley seed with 4% moisture content were damaged more by being stored after irradiation than seed with 8% moisture content. Since the time required to administer the low intensity doses was 80 hours but only a few minutes for the high intensity doses, the "storage effects" had sufficient time to do their damage only in those receiving the low intensity treatments.

Test Number 4—Because of what appeared to be storage effects at low irradiation intensities, a test was conducted to measure such effects. Seed at 12.5, 5.3, and 3.2% moisture contents were irradiated and stored for 24

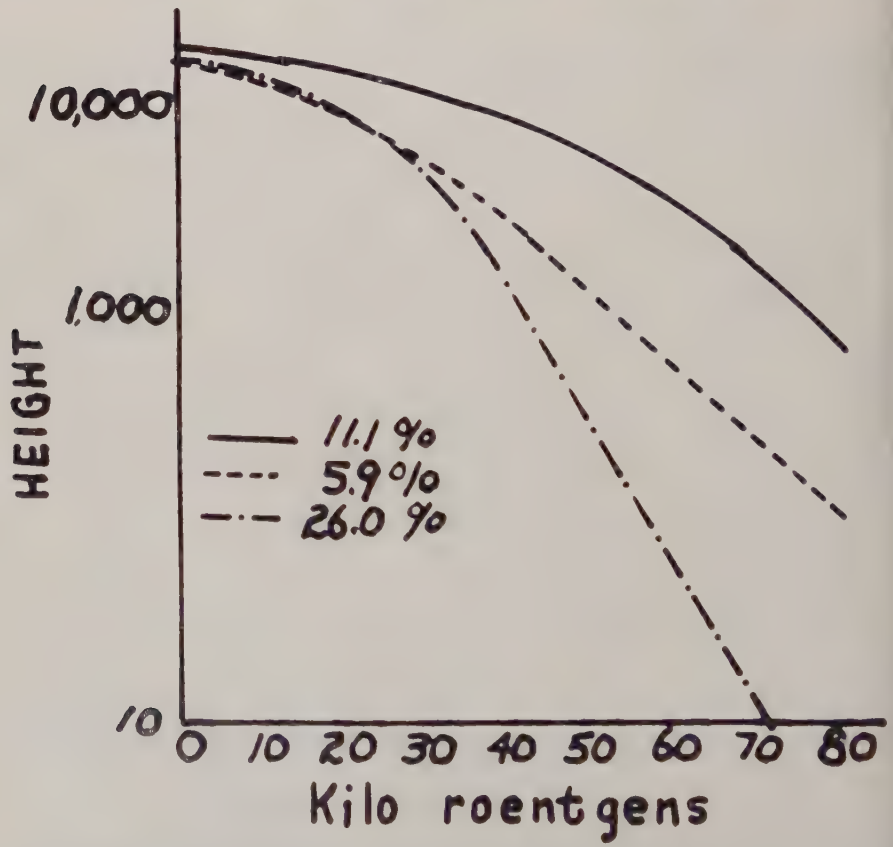

Figure 2.—Log of total height of seedlings in mm grown from irradiated oat seed having 11.1, 5.9, and 26% moisture content and receiving doses of gamma rays from 0 to 80 kiloroentgens.

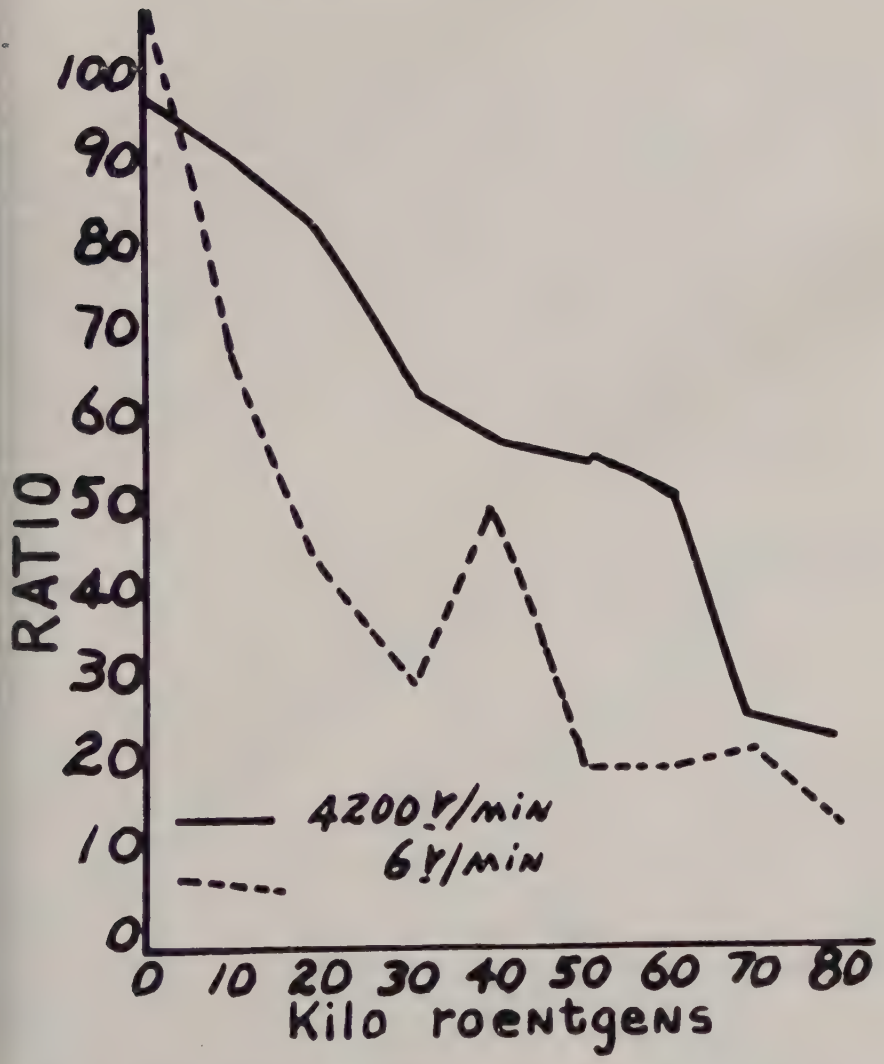

Figure 3.—Ratio (percents) of oat seedling heights grown from irradiated seed with 7.7% moisture to those with 9.6% moisture and irradiated at 4200 roentgens and 6 roentgens per minute.

hours before being planted. The next day seed of the same moisture contents were irradiated and wet immediately. The seed were irradiated dry and placed in water within one minute after the irradiation was completed. The water containing the seed was then placed in a vacuum immediately so that the seed were under a vacuum pressure within two minutes after being irradiated. The results from this test are presented in Figure 4. As can be seen in this figure, the storage increased the effects of the radiation on the 5.3 and 3.2% seed. The 12.5% seed were not influenced by being stored.

Test Number 5—For this test two lots of seed equilibrated at 6.8 and 9.6% moisture were used. The seed were irradiated and placed in water under a vacuum within 2 minutes after the irradiation treatments were completed. These seed were given 10 to 80 kilo roentgens at an intensity of 4200 roentgens per minute. Thus the treatment time ranged from slightly over 2 minutes to nearly 20 minutes. The response of seed with those two moisture contents are presented in Figure 5. As can be seen in this figure, there was almost no difference between them. This response can be compared with that presented in Figure 6, which is an identical test except that the seed were not wet under a vacuum immediately after irradiation and the seed with low moisture content had 7.7% instead of 6.8%. The seed in this test were planted in 1 hour after being irradiated. As can be seen in Figure 6, when the seed were not wet immediately under a vacuum, the 7.7% seed were much more sensitive than the 9.6% seed. This difference was eliminated when the seed were wet immediately, (Figure 5) even with seed of 6.8% moisture which should have been more sensitive than the 7.7% seed.

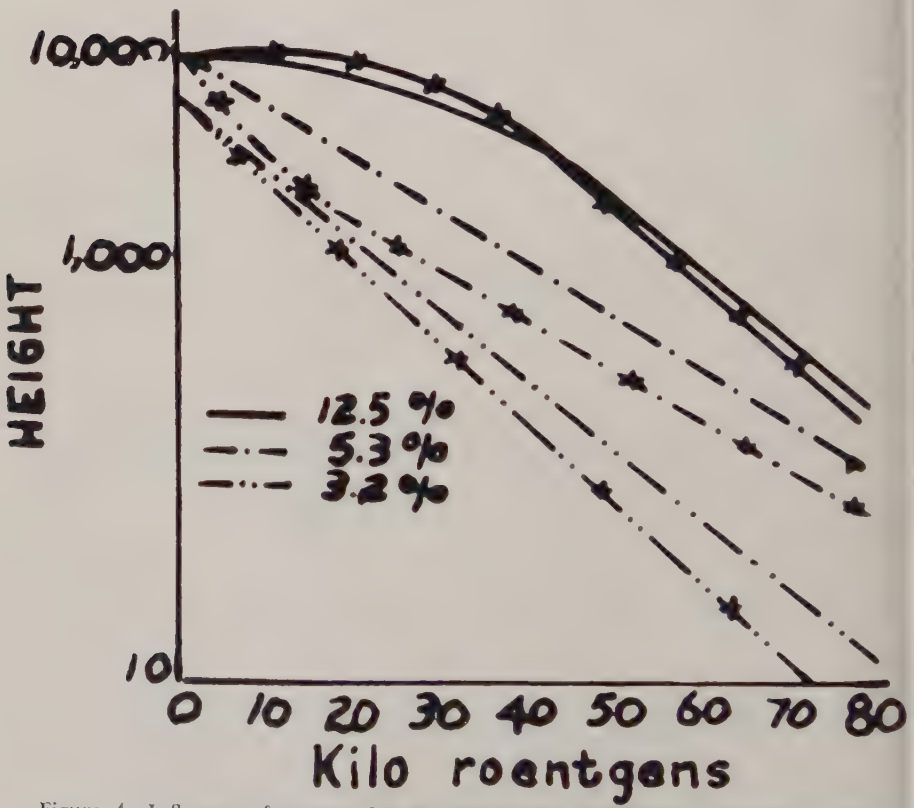

Figure 4.—Influence of storage for 24 hours after irradiation on seedling heights. Curves marked with crosses represent stored seed while unmarked curves represent planting immediately after irradiation.

DISCUSSION

Because data presented were collected on oats, it may be pertinent to point out how they differ from other such reports in the literature, most of which were collected on barley. These two plants belong to different genera. While they are similar in certain respects, they differ in others. For example, the oat used is a hexaploid, whereas most of the radiosensitivity research on barley was done with diploids.

A number of the reports (4, 6, 8) indicate that the radiosensitivity of barley decreases as the seed moisture content increases from 4% to 8%. At 8% the radiosensitivity reaches a plateau and does not change even at seed

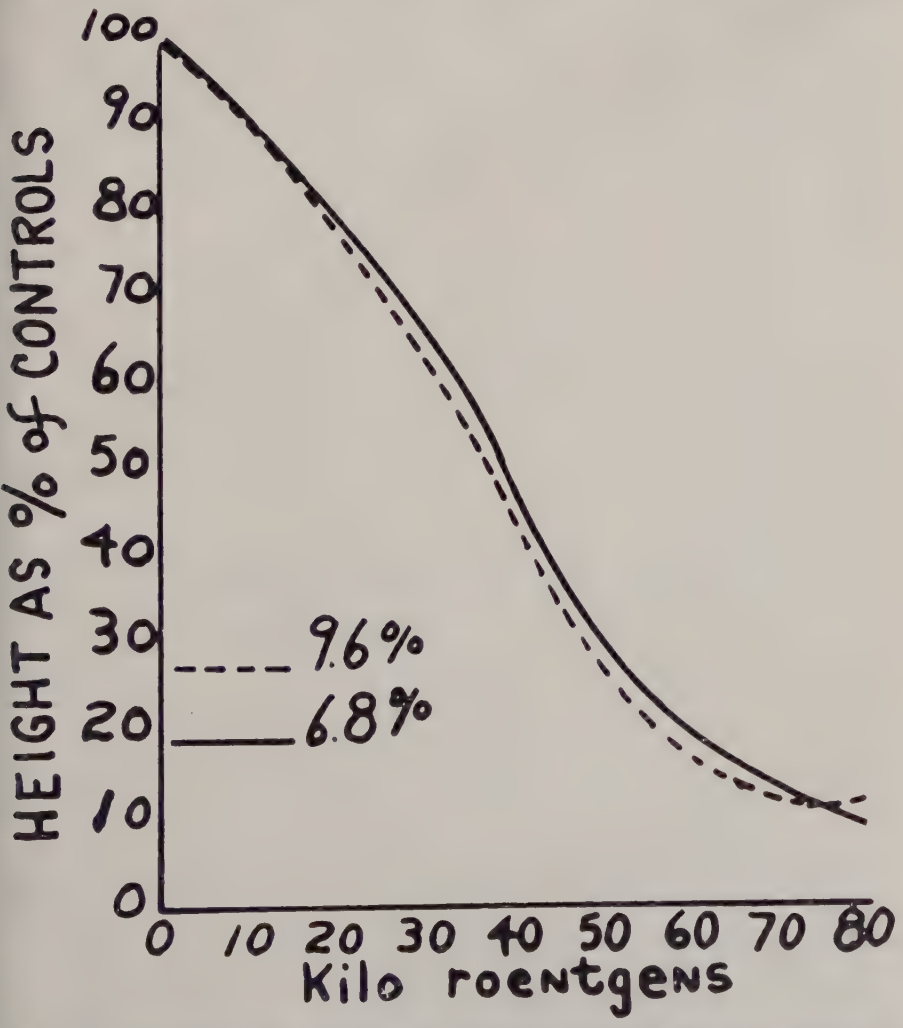

Figure 5.—Seedling heights, expressed as percent of controls, grown from irradiated oat seed with 9.6 and 6.8% moisture content, but wet immediately under vacuum after irradiation.

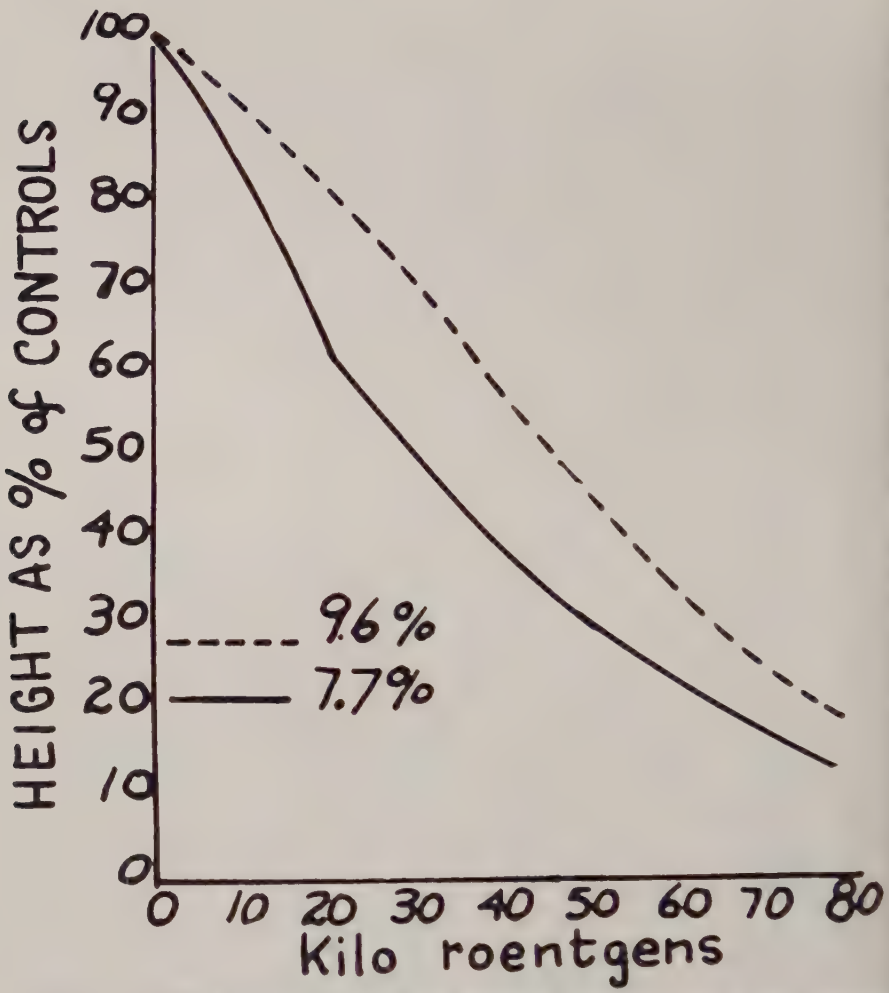

Figure 6.—Seedling heights, expressed as percent of controls, grown from irradiated oat seed with 9.6 and 7.7% moisture contents.

moisture contents as high as 60% (4), provided the metabolic rate is held in check during hydration. The data presented in this report show that oats also decrease in sensitivity when the seed moisture content increases from 3.2% upwards. However, they do not reach a plateau at 8% because the seed are much more sensitive at 7.7% than at 9.6%

The techniques used were not sensitive enough to measure seedling height differences between 9.6% and 12.5%, but storage studies (Table 1) show that even at these moisture contents oat seed responded. Furthermore, seed at 26% moisture were much more sensitive than seed at 11.1%. There is the slight possibility that increased metabolic rate could account for some of this. However, since the seed soaked only for one hour and at a temperature approaching 0 C, the metabolic rate could not increase very much. Thus one might assume from these data that oat seed do not reach

a plateau in their sensitivity but instead reach a minimum in radiosensitivity at moisture contents between 10 to 12% and then increase in sensitivity at lower or higher moisture contents. This assumption is supported by the report of Abrams and Frey (1).

It is very difficult to provide an explanation for a radiosensitivity curve of this shape. It is well known that free radicals are formed by irradiation, which are very reactive and non-specific with a short life span. Dr. A. D. Conger is of the opinion (personal communication) that these free radicals start chain reactions in the formation of new radicals which are less reactive, hence more specific and have longer lives. These specific radicals can account for the storage effects. Too, the presence of water in the tissue could cause a rapid reduction in the number of free radicals by recombination thereby proportionately prevent formation of specific radicals, and causing a reduction in the indirect effects of ionizing radiation. This explanation can also account for the increased radiosensitivity at low moisture contents; can account for the storage effects; can explain why the seed with 7.7% moisture when hydrated immediately after irradiation were no more sensitive than seed with 9.6% moisture. However, it does not explain the increased sensitivity of seeds at moisture levels over 10-12%.

SUMMARY AND CONCLUSIONS

Oat seed of the Victorgrain variety were brought to equilibrum over dehydrating agents to the following moisture contents: 3.2%, 5.9%, 6.8%, 7.5%, 9.6%, 10.3%, 11.1%, 12.5%, and 26.0%. Samples of each moisture content were irradiated with cobalt-60 gamma rays at dosages from 10 to 80 kilo roentgens. The irradiated seed were grown on germinating blotters in 4" x 4" plastic boxes in a growth room. The seedling heights were measured after 8 to 10 days and heights expressed as percentages of unirradiated controls.

The results from these tests show that the radiosensitivity of oats decreases as seed moisture content increases from 3.2% up to 9.6%. It reaches a minimum at about 10-12% and then increases again as the moisture content increases over 12%.

Oat seed at 9.6% and 7.7% moisture levels were irradiated at low and high intensities. The seed with 7.7% moisture were damaged much more in proportion to the 9.6% seed at low intensities.

Seed at 3.2, 5.9, and 12.5% were irradiated and stored for 24 hours, before being planted. Other samples were irradiated and planted immediately. Storing increased the radiation damage. The seeds with low moisture expressed the most "storage effects."

Seed at 7.7% and 9.6% moisture contents were irradiated and hydrated immediately under vacuum. The immediate hydration reduced the effects of irradiation on the 7.7% seed so that they expressed no more damage than the 9.6% seed.

The results are discussed and an hypothesis by Conger is used to explain them in part. This hypothesis is that the radiation induced very reactive, non-specific free radicals from less reactive specific long lived radicals. The presence of water in the tissue in some way probably by recombination reduces the frequency of specific radicals and thereby reduces the indirect part of the radiation damage.

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Effects of Liming on Yield and Value of Flue-Cured Tobacco in the Suwannee Valley Area[1]

H. L. BRELAND, W. L. PRITCHETT, AND H. W. LUNDY[2]

INTRODUCTION

The question of whether to lime soil used in a crop rotation system that includes flue-cured tobacco has been studied and discussed for many years (3, 4, 5). It is generally believed that the application of lime to soils used for flue-cured tobacco will result in a higher incidence of diseases and poor leaf quality. Therefore, lime is not generally recommended for this crop unless the pH is exceptionally low. However, when the calcium is very low in the soil, or the pH is below 5.2, it is recommended that adjustments be made through the application of dolomitic limestone (11).

Although flue-cured tobacco is grown in 29 of the 67 counties of the state, about 80 per cent of the total acreage is located in six counties in the Suwannee Valley area. The production of flue-cured tobacco is therefore confined largely to the well-drained sandy soils having a relatively low base exchange capacity. The pH, calcium and magnesium levels are quite low for many soils and have in many instances limited the production of peanuts, soybeans and other crops grown in the rotation with tobacco. However, when properly managed these soils produce good yields of all the crops in the rotation, as well as high quality leaf.

Even with the introduction of tobacco varieties more resistant to root-rot, and the fact that production is confined largely to the well-drained soils, the use of lime has not been encouraged. Although the low pH, calcium and magnesium levels may not be considered as critical for the production of tobacco at this time, it would be advantageous to know whether moderate lime applications would be beneficial or harmful to the tobacco.

LITERATURE REVIEW

Many references are available on the effects of liming soils for the production of tobacco. However, much of this work did not indicate what the soil reaction was before or after liming (4, 8, 10, 11). In certain in-

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stances the reduction in yield or quality may have been due to relatively heavy applications of lime or from applying lime on soils which already had a rather high pH (7, 8, 9).

The use of lime on the soil was found to be a desirable practice by Morgan, *et al* (6) if the pH and or calcium and magnesium levels were low. Roberts, *et al* (10) found that limestone was beneficial for the production of burley tobacco on depleted soils if applied at a moderate rate of not more than two tons per acre as an initial application. The average tobacco yield and price per pound was found to be higher by Moss, *et al* (7) from most plots where limestone had been added. This work represented a large number of plots in several locations. Anderson, *et al* (1) found that the addition of one ton of aid-slacked lime per acre raised the soil pH from 5.0 to 6.7. In each case higher tobacco yields were produced, indicating that considerable benefit was obtained from the treatment. Although the soil reaction was rather high, there was no incidence of black root-rot in the field. Garner, *et al* (4) found that some soils required additions of calcium to prevent a calcium deficiency showing up in the plants and avoid serious injury to the crop.

Darkis, *et al* (3) found that the calcium content of tobacco produced on limed plots was 21 percent higher than that produced on the unlimed plots. The increased calcium content was also accompanied by a slight increase in the potassium content of the leaf. This was not in agreement with Anderson's (1) or Morgan's (6) findings, but the decrease may have been predicted from McIntyre's (5) work.

The work of Darkis also showed that the tobacco produced on limed plots was higher in total nitrogen, lower in nicotine and lower in reducing and total sugars. The differences were +5.6, −6.8, −21.1 and 2.1 percent, respectively. It was not pointed out that the average differences in favor of not liming were relatively small in most cases. However, it was noted that the weather had considerable effect on the composition of the leaf, particularly with respect to the sugar content and that it may have caused some of the variation in the values obtained. It was also found that the tobacco produced on limed soil was of poorer quality and the market value less than that produced on the unlimed soils. Yet, the average yield obtained for all six years was higher on the limed plots than on the unlimed plots. The average increase in yield was 222 pounds per acre. The question was also raised about the effects of limestone applications on the release of increased amounts of nitrogen to the crop over a longer time. As a result the leaves would mature more slowly or fail to mature.

Garner, *et al* (4) found that a large proportion of the light-sands and sand loams were too low in magnesium for the successful production of tobacco unless it was applied in the fertilizer. As a result most flue-cured tobacco fertilizers now contain about two percent MgO.

METHOD OF PROCEDURE

A field experiment was established at Suwannee Valley Experiment Station to study the effect of lime applications on the production of flue-cured tobacco. The soil type selected was Klej fine sand, a deep well-drained soil commonly used for the production of flue-cured tobacco in the state. A different area was used each year so that the limestone applications could be made on soil that had not been previously limed. Each

plot was 12 by 50 feet (600 square feet or 1 72.6 acre), making it possible to have four rows fifty feet long on each plot. Hicks Broadleaf variety of tobacco was grown, with about 9000 plants per acre. The two center rows were harvested for determining yield, grade, value, composition, etc. The tobacco was graded by government inspectors and the values calculated on the basis of the prices paid for the different grades. Three replications were used for the different treatments each year except for 1959 when 6 replications were used. The 1958 crop was drowned out and therefore no yield was obtained.

Soil samples were collected and analyzed (2) from each area before and after the treatments were made. The average pH, calcium, magnesium, phosphorus and potassium levels were fairly low on the areas before treatments were made (Table 1).

TABLE 1.—THE AVERAGE SOIL TEST VALUES OBTAINED ON PRE-FERTILIZATION SAMPLES FROM THE DIFFERENT AREAS.

Crop Year	pH	Pounds per Acre			
		CaO	MgO	P_2O_5	K_2O
1956	5.1	98	39	24	113
1957	5.6	56	35	34	68
1959	5.2	125	15	33	69

A base fertilizer application of 1800 pounds per acre of a 3-9-12 fertilizer containing 2 percent chlorine and 2 percent magnesium was applied to all plots. Cultural and irrigation practices common to the area were used throughout. All other treatments are given in Table 2.

TABLE 2.—KIND AND AMOUNT OF DIFFERENT LIMING MATERIALS APPLIED.

Treatment	Pounds per acre
1. Check	0
2. High Calcic Lime	1,000
3. High Calcic Lime	2,000
4. High Calcic Lime	4,000
5. Calcium Sulfate	3,400
6. Dolomitic Lime	1,000
7. Dolomitic Lime	2,000
8. Dolomitic Lime	4,000
9. Magnesium Sulfate	1,600

The calcium sulfate contained 31.5 percent CaO and the amount applied was equivalent to the calcium in 2000 pounds of high calcic limestone. The magnesium sulfate contained 28.0 percent MgO and the amount applied was equivalent to the magnesium in 2000 pounds of dolomitic limestone. Both materials were finely ground and it was felt that a sieve analysis was not necessary. The percent purity and the sieve analysis of the high calcic and dolomitic limestone used are given in Table 3.

TABLE 3.—THE PERCENT PURITY AND SEIVE ANALYSIS OF THE LIMING MATERIALS USED.

Determination	Limestone	
	Dolomitic Percent	High Calcic Percent
Calcium carbonate equivalent	95.2	96.4
Calcium carbonate	58.9	93.0
Magnesium carbonate	38.1	2.8
Passing 20-mesh sieve	97.5	92.6
Passing 60-mesh sieve	70.5	. .
Passing 80-mesh sieve	. .	68.6
Passing 100-mesh sieve	56.0	48.6

RESULTS AND DISCUSSION

The average soil test values obtained from all replications for 1956, 1957 and 1959 are given in Table 4. The samples were collected in May approximately five months after the liming materials were applied.

The different treatments had very little effect on either the soil phosphorus or potassium values except that the calcium sulfate reduced the potassium value slightly.

It was interesting to note that the change in soil pH was about the same for the applications of both high calcic and dolomitic limestones (Figure 1). The amount of change was from 0.2 to 0.3 of a pH unit for each 1000 pounds of limestone applied per acre. Similar results should be obtained on other well-drained acid soils in the area provided the purity and fineness of the liming materials are about the same.

There was an average increase in the calcium soil test value of 251 pounds per acre of CaO for each 1000 pounds of high calcic limestone applied per acre. Since the dolomite contained only about 59 percent calcium carbonate, each 1000 pounds raised the calcium soil test value by an average of only 110 pounds per acre of CaO. However, the magnesium values were also increased by an average of 56 pounds of MgO per acre with the same application.

The application of calcium sulfate in amounts comparable to the calcium applied in 2000 pounds of high calcic limestone raised the soil test

TABLE 4.—AVERAGE SOIL TEST VALUES OBTAINED APPROXIMATELY FIVE MONTHS AFTER MAKING LIME APPLICATIONS.

Treatment	pH	Pounds per acre			
		CaO	MgO	P_2O_5	K_2O
1	5.2	120	48	44	87
2	5.5	314	48	41	87
3	5.7	617	58	53	84
4	6.0	1361	57	46	84
5	4.8	274	42	52	57
6	5.5	233	103	42	94
7	5.8	323	155	43	92
8	6.1	579	293	55	88
9	5.1	120	56	51	84

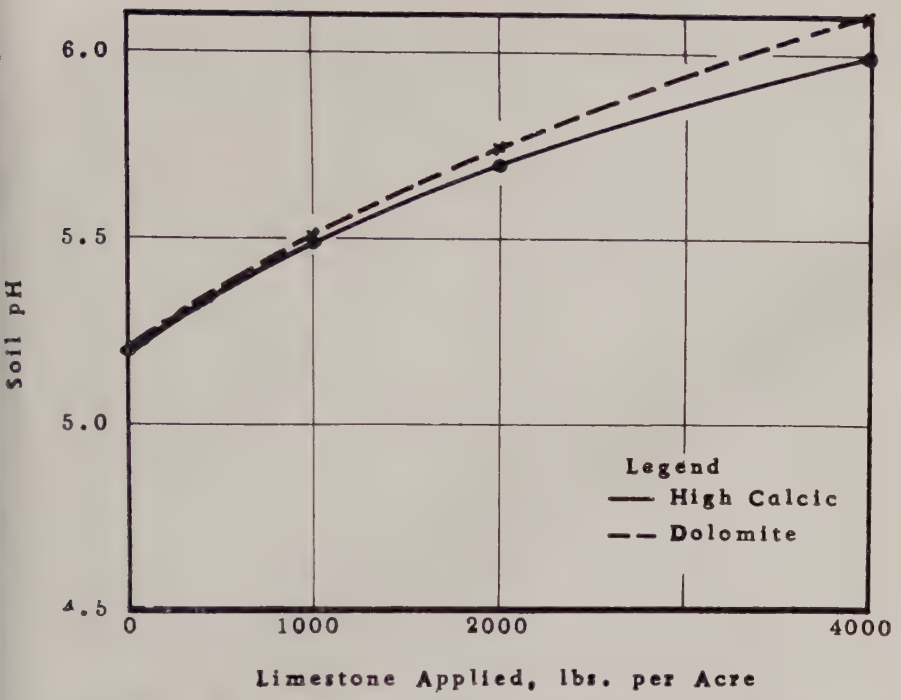

Figure 1.—The Effect of Different Rates of Limestone Applications on the pH of the Soil.

value by only 154 pounds per acre of CaO. When the same amount of calcium was applied in high calcic limestone, the value was increased by 497 pounds per acre of CaO. The average pH of the soil decreased by 0.3 of a pH unit as a result of the application of calcium sulfate.

When 1600 pounds per acre of magnesium sulfate were applied, the average increase in the MgO content of the soil was only about 8 pounds per acre. However, when a comparable amount of magnesium was applied as dolomite, the MgO content of the soil was increased by 107 pounds per acre.

The very low recovery of calcium and magnesium from the soil when applied as the sulfate indicates that there is a much greater loss of these nutrients by leaching than is generally believed. Similar losses of magnesium from the surface six inches of soil have been noted for several years when applied as the sulfate. The areas were sampled at four depths, 0-6, 6-12, 12-18 and 18-24 inches, in 1959 in an attempt to recover more of the magnesium. However, the soil analysis showed only a slight increase in the magnesium content of the samples at the 18-24 inch depth on the areas receiving the magnesium sulfate applications. The increase accounted for only a small amount of the magnesium applied.

If magnesium can be leached from acid soils in such large amounts, it would be reasonable to believe that the two percent magnesium included in most flue-cured tobacco fertilizers may be barely enough to meet the minimum requirements of the plants.

Applications of both high calcic and dolomitic limestones increased the average yields and acre values of the flue-cured tobacco as shown in Figures 2 and 3. The yields and values were increased by all treatments over that obtained from the check. The maximum increases were 161 pounds and $68.30 per acre for the high calcic and 391 pounds and $221.47 per acre for the dolomitic limestones.

The maximum yield and value was obtained with the 2000 pound rate of high calcium limestone. When the rate was increased to 4000 pounds per acre, no further increases were obtained (Figure 2). The calcium sulfate treatment produced a yield of 214 pounds for a value of $56.51 over that of the check. This was only 47 pounds and $11.77 less than that obtained by the 2000 pound rate of high calcic limestone for the three year period (Figure 2).

This indicates that the plants may have derived more benefit from the calcium supplied to the soil than from the change in soil pH. As the calcium values in the soil increased, both the yield and value of the tobacco increased up to about 600 pounds per acre of CaO (Figure 4).

Where dolomite was applied, the tobacco yields and values were increased up to and including the highest rate (Figure 3). It was also found that as the magnesium levels increased in the soil up to 293 pounds of MgO per acre, both the yield and value of the tobacco increased (Figure 5). The application of magnesium sulfate produced an average yield of 102 pounds per acre and a value of $33.20 higher than that of the check. However, neither the yield nor value of the tobacco was as large as that obtained with the calcium sulfate application.

The yield and value of the flue-cured tobacco produced with the 4000 pound application of dolomitic limestone was found to be significantly

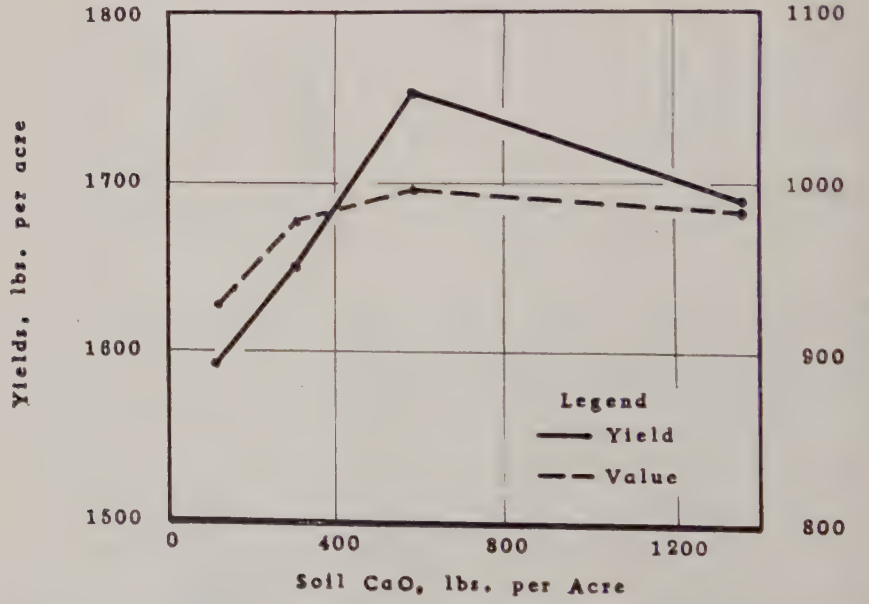

Figure 2.—The Effect of High Calcic Limestone Applications on the Average Yield and Value of Flue-Cured Tobacco.

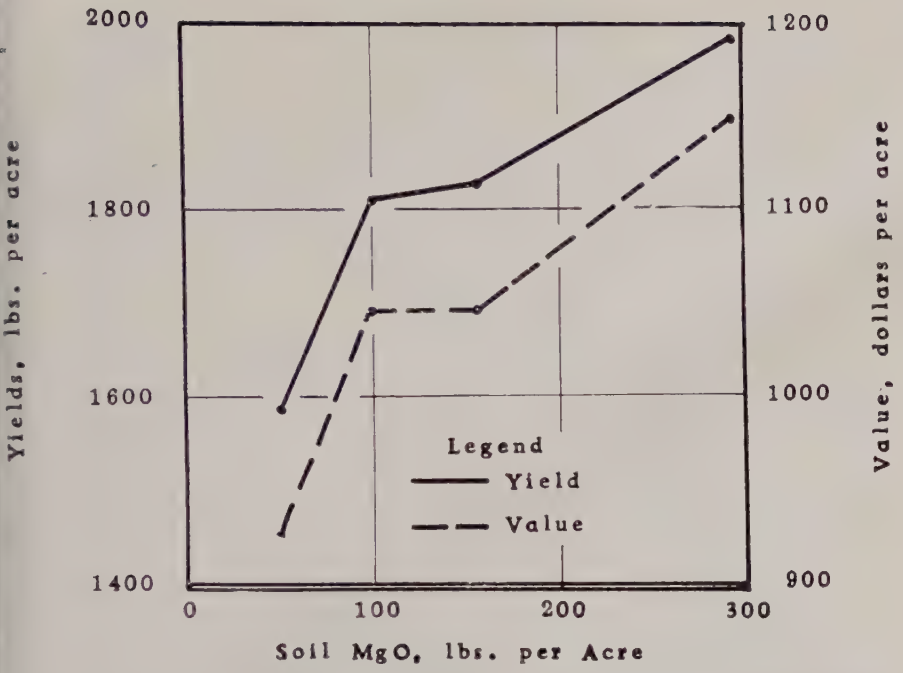

Figure 3.—The Effect of Dolomitic Limestone Applications on the Average Yield and Value of Flue-Cured Tobacco.

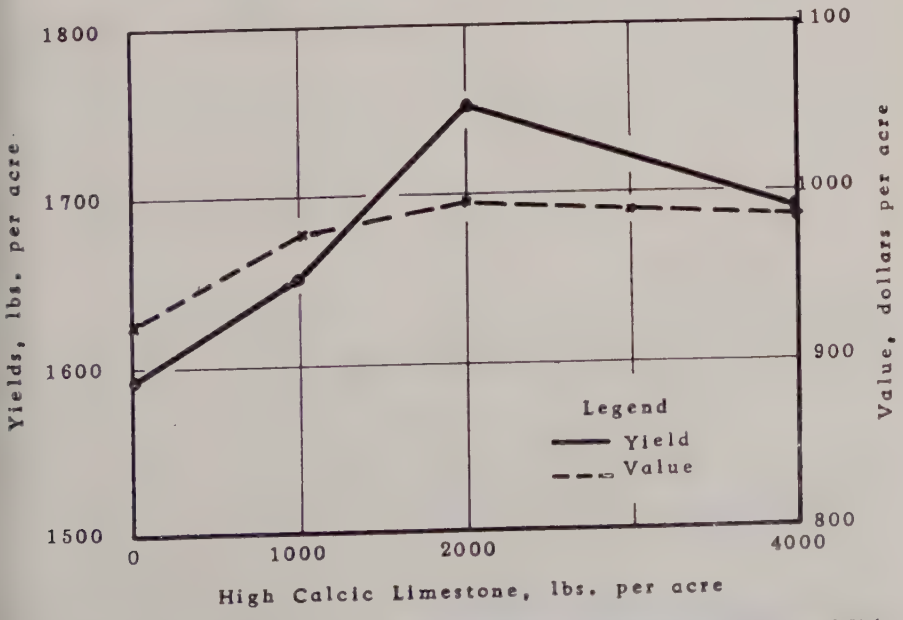

Figure 4.—The Effect of Various Levels of Calcium in the Soil on the Yield and Value of Flue-Cured Tobacco.

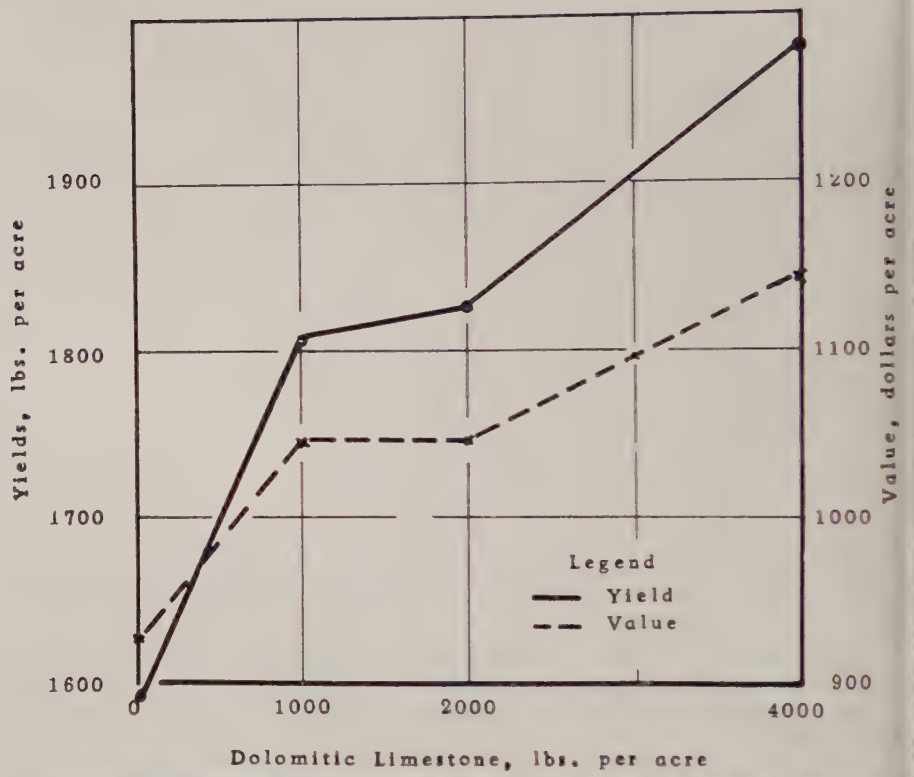

Figure 5.—The Effect of Various Levels of Magnesium in the Soil on the Yield and Value of Flue-Cured Tobacco.

TABLE 5.—THE AVERAGE YIELD AND ACRE VALUE OF FLUE-CURED TOBACCO OBTAINED BY APPLYING DIFFERENT RATES AND SOURCES OF LIMESTONE.

Treatment[1]	CROP YEAR					
	1956		1957		1959	
	Yield Lbs/A	Value $/A	Yield Lbs/A	Value $/A	Yield Lbs/A	Value $/A
1. Check	1755	967.79	1425	823.08	1593	991.00
2. 1000 Hi Calcic Lime	1692	942.49	1585	933.94	1684	1056.37
3. 2000 Hi Calcic Lime	1972*	1015.94*	1480	850.90	1804	1119.92
4. 4000 Hi Calcic Lime	1484	787.46	1679	969.63	1903*	1195.67
5. 3400 $CaSO_4$	1669	887.61	1646	950.14	1801	1113.64
6. 1000 Dolomite	1995*	1076.59*	1508	863.76	1926*	1199.74
7. 2000 Dolomite	2066*	1086.15*	1617	930.34	1795	1091.72
8. 4000 Dolomite	1997*	1064.54*	1824*	1053.95	2126*	1327.78
9. 1600 $MgSO_4$	1980*	1036.90*	1400	809.93	1701	1034.65
L.S.D. (5%)	92.98	47.51	290.90	181.71	277.73	217.70

[1]Each plot received a base application of 1500 pounds per acre of a 3-9-12 fertilizer containing 2 percent Cl. and 2 percent MgO.

*Significant (5%) increases over check.

higher, statistically, than the check for the three years (Table 5). In 1956 five of the treatments, 3, 6, 7, 8 and 9, were found to have a yield and value greater than that of the check. However, in 1957 the yield and value of only treatment 8 was significantly different from the check. Some of the treatments were adversely affected by a wet area in the field in 1957. This undoubtedly accounts for some of the low yields and the large within block variability which resulted in large L.S.D. (least significant differences) values. In 1959, treatments 4, 6 and 8 produced yields that were significantly greater than the check but only treatment 8 produced tobacco with a value significantly greater than the check.

SUMMARY

The purpose of this study was to investigate the effects of different sources and rates of liming materials on the production of flue-cured tobacco.

It was found that applications to the soil of either high calcic or dolomitic limestone resulted in a pH change of about the same magnitude. The change was from 0.2 to 0.3 of a pH unit for each 1000 pounds of limestone applied per acre. The application of the different liming materials also increased average yields and values of the tobacco for the three year period. The maximum increases for yield and value were 161 pounds and $68.30 for the application of one ton of high calcic limestone per acre. A higher rate did not increase either the yield or value of the tobacco. The maximum increases in yield and value for dolomitic limestone were 391 pounds and $221.47 per acre, obtained with the highest rate, 4000 pounds per acre.

The production of flue-cured tobacco was not adversely affected by the application of liming materials. In fact, the yield and value were both increased by applications of either calcium or magnesium or both. Therefore, if soil test results show that the pH, calcium and magnesium values are low, the application of limestone would probably be beneficial on deep, well-drained soils in the Suwannee Valley area. Since increases in yield and value of the tobacco were obtained with both calcium and magnesium applications, the use of dolomitic limestone would be preferred.

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Effects of Nitrogen Fertilizer on the Yield and Composition of Flue-Cured Tobacco[1]

W. L. PRITCHETT, H. L. BRELAND AND H. W. LUNDY[2]

Flavor and taste of tobacco are derived primarily from its nitrogen compounds. A strong, pungent irritating smoke is related to high nitrogenous constituents, while a flat smoke is associated with low values, according to Elliot and Vickery (5). They reported further that "all essential elements play an important role in flue-cured tobacco production, but applications of nitrogen exert the greatest effect on leaf quality." Nitrogen, perhaps the most difficult of the plant nutrients to control at a desired level of availability in the soil, is also closely related to yields (2). A low nitrogen level will result in low yield and value of the tobacco. On the other hand, over-fertilization with nitrogen has resulted in the production of tobacco containing undesirably large amounts of nicotine and other nitrogenous compounds, small amounts of sugar, off color and poor quality in general, according to Clark (1).

It is important to control the nitrogen supply for tobacco so that adequate amounts are provided for rapid early growth with a gradual reduction in the supply as growth progresses. A slight deficiency should occur during the later stages of growth. This usually results in acceptable yields of good quality tobacco with a relatively low nicotine content.

In recent years, the increased consumption of filter-tipped cigarettes has brought about some basic changes in tobacco quality concepts. Market demands for tobacco with low nicotine content have changed to tobacco with a higher content of nitrogen compounds, so as to provide for acceptable flavor and taste in cigarettes using filter tips (6).

Flue-cured tobacco produced on Florida's sandy soils has been noted for its good quality (1) with a high sugar and relatively low nicotine content. Some increase in nicotine content of tobacco would probably be acceptable, under present conditions. However, it is not known to what extent yields can be increased by larger nitrogen applications without undue increases in nicotine content and lowering of the value of the leaf. This work was undertaken to study the effects of nitrogen fertilization on yields, value and composition of tobacco leaves.

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EXPERIMENTAL PROCEDURES

Soils: The Blanton and Klej soils used for these experiments were in old cultivated fields that had been idle for two or more years. The organic matter of the surface six inches of soil ranged from 1.5 to 2.3 percent. The total nitrogen content was in the range of 0.04 to 0.07 percent and the nitrate production during 14 days of incubation in the laboratory ranged from 22 to 35 ppm.

Hicks Broadleaf variety of tobacco was planted in all experiments at the rate of approximately 9,000 plants per acre. Plot size was 12 by 50 feet (1/72 acre). The tobacco in all experimental areas was irrigated, cultivated and harvested according to generally accepted methods. The tobacco was graded by government inspectors and the value calculated on the basis of prevailing prices for the various grades.

Field experiments No. 1: In preliminary experiments, conducted in 1956 and 1957 at the Suwannee Valley Station, organic materials were added to the soil at the rate of approximately two tons per acre, with and without 33.5 pounds per acre of additional nitrogen. In 1956 corn cob and shuck meal were applied to Klej fine sand, while in 1957 bahiagrass straw was applied to Blanton fine sand. In both experiments the organic materials and ammonium nitrate (Table 1) were disked into the non-fumigated surface soil about three months before planting. A base application of 1800 pounds of 3-9-12 fertilizer was applied to all plots in a split application. The treatments were part of a larger experiment in which rates and sources of liming materials were also studied.

Field experiment No. 2: The experiments conducted at the Suwannee Valley Station in 1958 and 1959 were laid out using a factorial design in which four rates of nitrogen, three rates of potash and two levels of dolomitic limestone were applied. A base application of 1500 pounds per acre of 3-9-9 tobacco fertilizer was applied uniformly in rows to all plots. The base fertilization was made in two equal applications; one-half immediately prior to planting and the other applied two weeks later. The base treatment of 45-135-135 was calculated to supply sufficient phosphorus, but a minimum of nitrogen and potassium for tobacco on this soil. The four nitrogen sidedress treatments used in 1958 supplied 0, 15, 30 and 45 pounds of nitrogen per acre as ammonium nitrate. In 1959, these treatments were tripled, resulting in rates of 0, 45, 90 and 135 pounds per acre. The nitrogen treatments are given in Tables 2 and 3. The soil was fumigated about two weeks before planting in these two experiments.

One half of the plots received an application of 2000 pounds per acre of dolomitic limestone about three months before planting; however, the lime and potash treatments will not be discussed in this paper, except as they affect the response to nitrogen fertilization.

Chemical Analyses: Approximately 20 leaves were randomly selected from both the second and fourth primings for the determination of the chemical composition of the tobacco. These leaves were oven-dried and ground after removal of the mid-rib. Leaves from the two primings were analyzed separately, however, the results are reported as averages of the two primings, unless otherwise stated. Total nitrogen was determined by the standard Kjeldahl procedure. The Denige-Truog method was used for the colormetric determinations of phosphorus. Potassium, calcium

and magnesium were determined with flame spectrophotometers. Calcium and magnesium were determined after the solutions were passed through a column of Dowex 1-X8 anion exchange resin. Total alkaloids, nicotine and nornicotine-type alkaloids were determined according to the method of Cundiff and Markunas (3). In this method, an alkaline tobacco mixture is extracted with a benzene-chloroform solution and aliquots of the extract are titrated with standard perchloric acid. The acetylations of base-type alkaloids provides a means of determining nornicotine-type alkaloids in the presence of nicotine.

RESULTS

Organic matter trials: The yield and value per acre of tobacco grown in the preliminary experiments in 1956 and 1957 were generally increased by the use of organic materials (Table 1). However, due to the large within-block variability (as expressed by the large L.S.D. values), only the yields of the 1956 crop were significantly increased by supplemental organic matter and organic matter plus nitrogen. The organic materials generally increased the nitrogen, calcium and magnesium contents of the leaves, but did not affect the phosphorus and potassium contents. The composition was affected to a greater extent where supplemental nitrogen was added along with the organic materials. This was probably due to more rapid decomposition of the organic materials in the presence of the extra nitrogen.

The nitrogen content of good quality flue-cured tobacco leaves was reported to be about 1.8 percent in 1952 (4). In 1956, correspondence with the major tobacco companies indicated that 1.5 to 2.0 percent nitrogen was a desirable range for flue-cured tobacco. The nitrogen contents of tobacco leaves from these two experiments were below this range—even from plots receiving the organic matter and extra nitrogen. The nitrogen

TABLE 1.—THE EFFECT OF ORGANIC MATERIAL AND NITROGEN ON THE YIELD, VALUE AND COMPOSITION OF FLUE-CURED TOBACCO.

TREATMENTS[1]		Yield	Value					
Material	Pounds per Acre	Pounds per Acre	Dollars per Acre	Composition, % N	P	K	Ca	Mg
		1956						
1. Check	....	1755.5	967.8	1.30	0.203	3.60	1.96	0.340
2. Organic Material	4000	2025.9	1038.9	1.36	0.240	3.93	2.41	0.437
3. Organic Material +	4000							
Ammonium Nitrate	100	1887.6	998.7	1.44	0.215	3.86	2.60	0.450
L.S.D.*		93.0	47.5	0.116	0.105	0.448	0.406	0.050
		1957						
1. Check	....	1425.6	823.1	1.12	0.310	3.81	1.42	0.92
2. Organic Material	5000	1495.8	816.3	1.12	0.379	3.52	1.69	0.91
3. Organic Material +	5000							
Ammonium Nitrate	100	1619.8	955.0	1.17	0.350	3.27	1.77	0.98
L.S.D.*		290.9	181.7	0.096	0.112	0.577	0.342	0.059

[1]Base application of 1600 pounds of 3-9-12 made to all plots.
*Least significant difference at 5% level of significance.

content was generally highest in leaves from plots producing the highest yields and during the year of most favorable growth.

Nitrogen sidedressing trials: The effects of sidedressing of ammonium nitrate on yield and value per acre and chemical composition of tobacco receiving a base application of 1500 pounds of a 3-9-9 fertilizer per acre are given in Table 2 and 3. These values are the averages of 12 replications for each year. In both years, yields were increased with increasing rates of nitrogen. However, the 1958 yields resulting from sidedressings of 15, 30 and 45 pounds of nitrogen were not significantly higher than yields in check plots (which received only the base application containing 45 pounds of nitrogen at planting). In 1959, a year of higher rainfall and more favorable conditions during the growing season, yields were significantly increased at all levels of nitrogen up to a total of 180 pounds.

Crop value, a product of the yield per acre and price per pound, should be closely related to the yield. This was found to be true and is shown graphically in Figures 1 and 2. The linear regressions of yield and value on nitrogen rates were found to be highly significant for both years. In the 1958 experiment, crop value increased at the rate of $8.92 for every 15 pounds of nitrogen applied as sidedressing. However, yield increased to a greater extent than value, due to a lower price per pound at the higher rates of nitrogen. The yield regression was 43.8 pounds of tobacco per 15 pounds of nitrogen.

The price received per pound of tobacco was not materially influenced

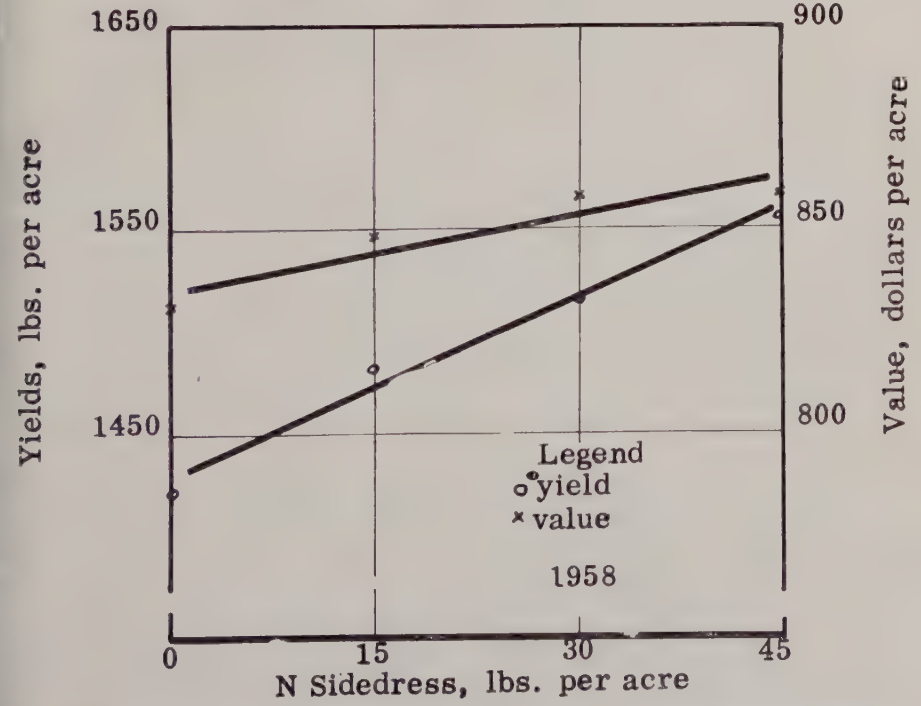

Figure 1.—The Effect of Nitrogen Sidedress Applications on the Yield and Value of Flue-Cured Tobacco in 1958.

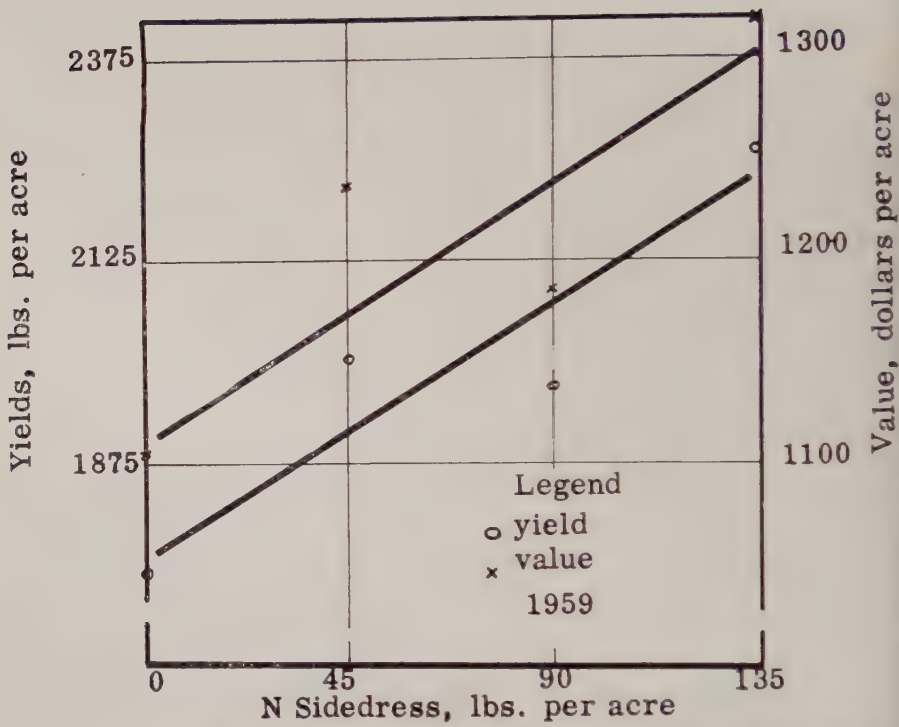

Figure 2.—The Effect of Nitrogen Sidedress Applications on the Yield and Value of Flue-Cured Tobacco in 1959.

by nitrogen sidedressing in 1959 (Table 2). The yield increase for each 15 pounds of nitrogen was 50.6 pounds with a value of $20.02 per acre. The yield increace per 15 pounds of nitrogen was not greatly different in these two experiments, but the increase in value per unit of nitrogen was more than twice as large in the 1959 experiment.

The relationship of nitrogen fertilization to the mineral content of the tobacco was not particularly striking. However, there was a significant increase in calcium and potassium content of the leaves from plots that

TABLE 2.—THE YIELD, VALUE AND COMPOSITION OF TOBACCO FERTILIZED WITH VARIOUS RATES OF NITROGEN IN 1958.

N applied lbs/acre		Yield Pounds per Acre	Value Dollars per Acre	Percent in oven-dry leaf (mid-rib removed)				
Sidedress	Total			N	P	K	Ca	Mg
0	45	1420	830.77	1.41	0.29	3.01	1.52	1.16
15	60	1482	849.73	1.60	0.28	2.92	1.78	1.21
30	75	1515	858.68	1.62	0.27	3.10	2.06	1.31
45	90	1555	857.52	1.70	0.28	3.50	2.09	1.31
L.S.D.*		155	95.41	0.10	0.04	0.19	0.13	0.19

*Least significant difference at 5% level of probability.

TABLE 3.—THE YIELD, VALUE AND COMPOSITION OF TOBACCO FERTILIZED WITH VARIOUS RATES OF NITROGEN IN 1959.

N applied lbs/Acre		Yield Pounds per Acre	Value Dollars per Acre	Percent in oven-dry leaf (mid-rib removed)							
Sidedress	Total			Nicotine	Nor-nicotine	Total Alkaloids	N	P	K	Ca	Mg
0	45	1740	1103.55	0.78	0.060	0.84	1.25	0.97	3.01	1.26	0.54
45	90	2006	1235.44	1.29	0.068	1.37	1.71	1.03	3.57	1.98	0.73
90	135	1964	1181.43	1.40	0.091	1.50	1.95	0.97	3.62	2.22	0.78
135	180	2260	1321.83	1.43	0.093	1.53	2.10	1.06	3.89	2.49	0.82
L.S.D.*		227	146.53	0.08	------	0.09	0.09	0.03	0.25	0.32	0.12

*Least significant difference at 5% level of probability.

received the higher rates of nitrogen (Table 2 and 3). These two elements have been reported to be positively related to leaf burn and quality (5). The potassium content of leaves was found to be considerably higher and the calcium content lower than values reported for good quality flue-cured tobacco (4, 5).

The greatest influence of nitrogen on tobacco composition was in the nitrogenous constituents. The total nitrogen content of leaves from tobacco receiving various rates of nitrogen sidedressing are given in Table 2 for 1958 and in Table 3 for 1959. An increase of 0.09 percent nitrogen in the leaves was obtained for each 15 pounds of nitrogen per acre. Elliot and Vickery (5) reported that "flue-cured tobaccos containing 1.6 to 2.3 percent total nitrogen give the most desirable smoking quality." However, in these experiments only tobacco that received a total of 90 pounds or more of fertilizer nitrogen were within this range.

The total alkaloids, nornicotine (primary and secondary amine alkaloids) and nicotine (tertiary amine alkaloids) for the 1959 experiments are given in Table 3. Both nicotine and total alkaloids significantly increased with increasing rates of nitrogen. The linear regression of nicotine on

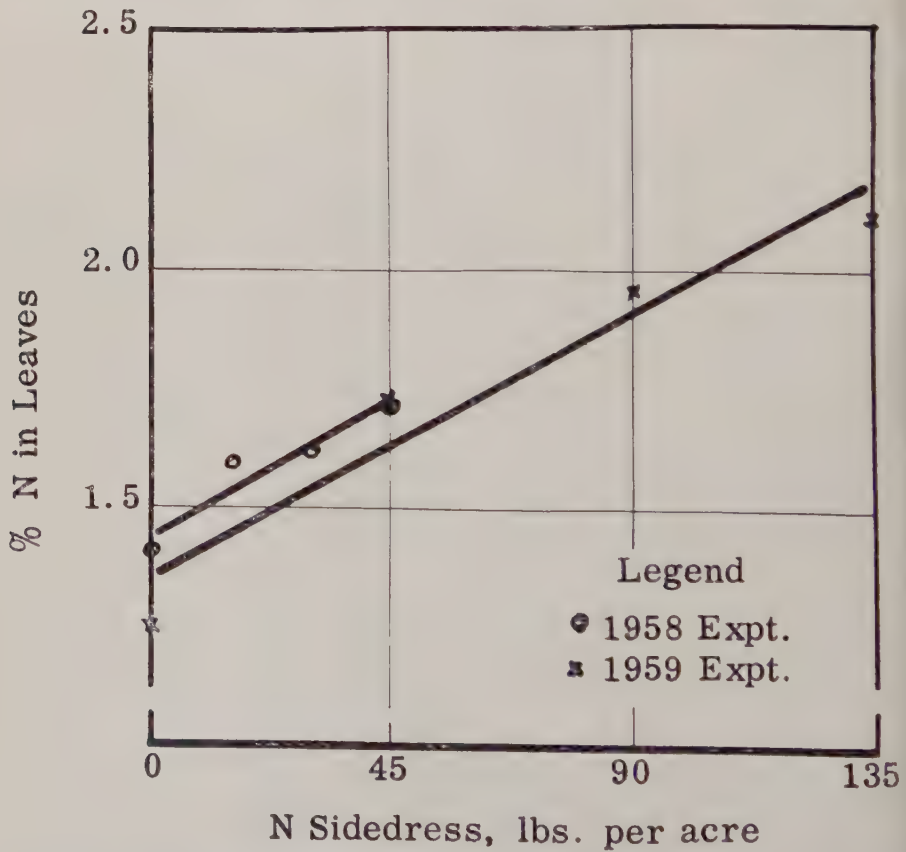

Figure 3.—The Effect of Nitrogen Sidedress Applications on the Nitrogen Content of Flue-Cured Tobacco in 1958.

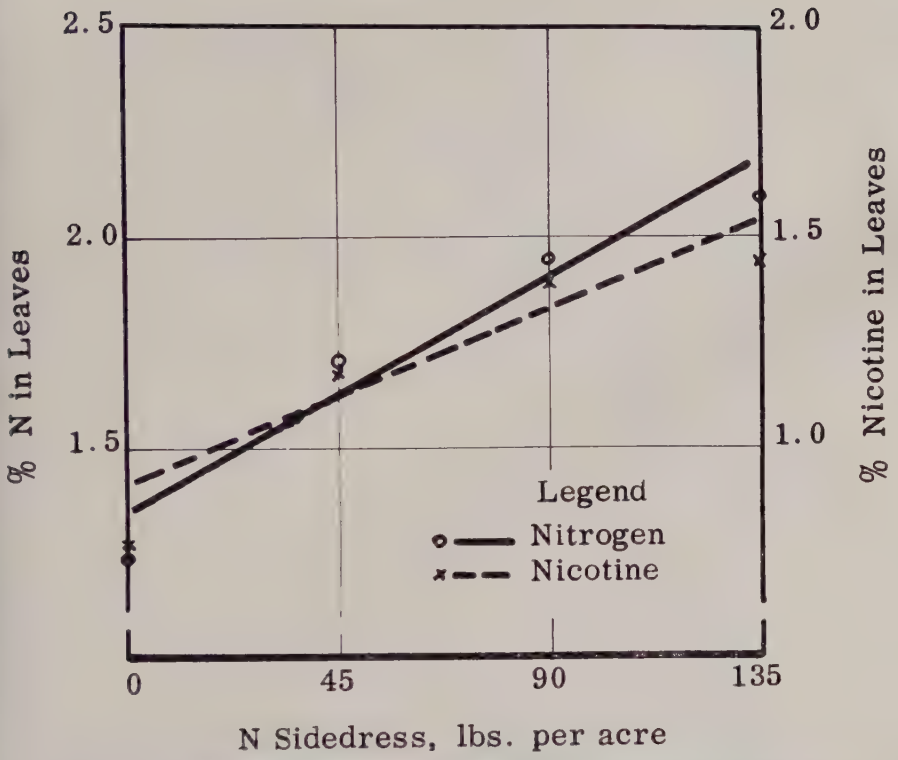

Figure 4.—The Effect of Nitrogen Sidedress Applications on the Nitrogen Content of Flue-Cured Tobacco in 1959.

nitrogen rates was highly significant, increasing by 0.07 percent for each 15 pounds of nitrogen applied (Figure 4). The quadratic regression was also significant, indicating that the nicotine content did not increase as rapidly at the higher rates as at the lower rates. The relationship of total nitrogen to nicotine in the leaves is shown in Figure 5. Each one percent increase in nitrogen increased the nicotine content of the leaf about 0.7 percent.

The average nicotine contents of leaves from the second and fourth primings were 1.01 and 1.45 percent, respectively.

SUMMARY

Nitrogen compounds greatly influence the chemical composition of tobacco which in turn affects the smoking quality of tobacco. Florida-grown flue-cured tobacco is generally medium to low in nicotine and other nitrogenous compounds, but the amounts of these constituents were affected by nitrogen fertilization. In experiments at the Suwannee Valley Station, organic matter had little influence on yield and nitrogen content; however, inorganic nitrogen sidedressings applied up to 135 pounds per acre gave the following results:

1. Yields were increased at all the levels of application, however, only in the year of relatively high rainfall (1959) were the yields increased significantly.

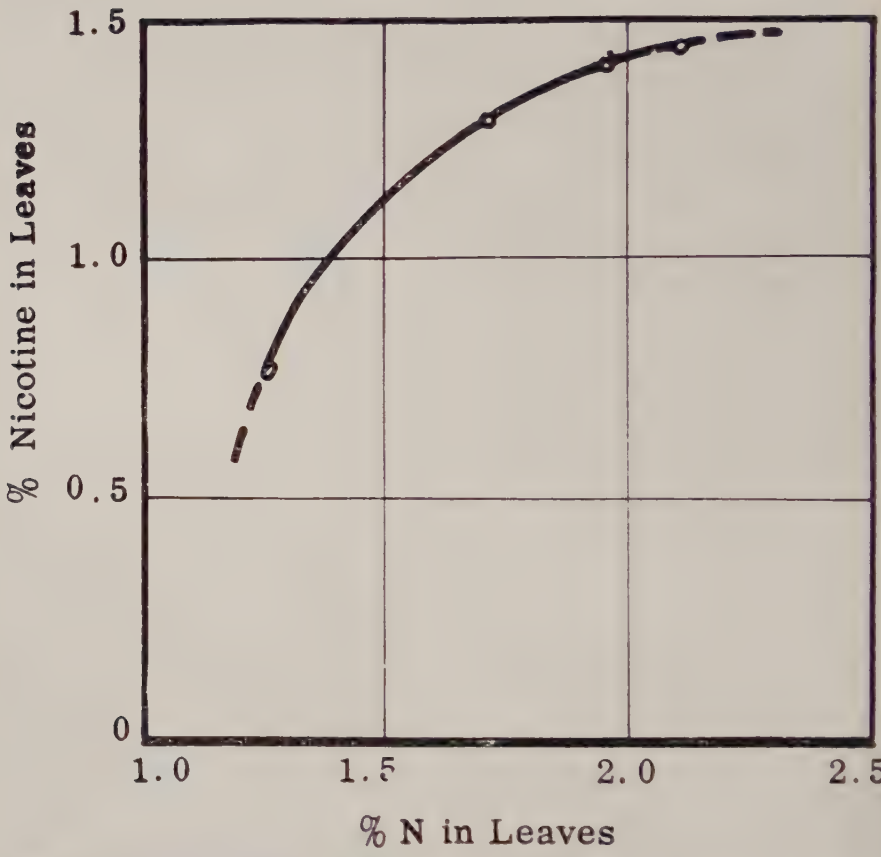

Figure 5.—The Relationship of Nitrogen Content to Nicotine Content in Tobacco Fertilized With Various Rates of Nitrogen in 1959.

2. Mineral composition was not greatly affected, except that potassium and calcium contents were increased with increasing rates of nitrogen. Leaf content of potassium was higher and calcium content lower than in flue-cured tobacco of other areas.

3. Total nitrogen and nicotine contents were generally lower than values usually associated with good quality tobacco. Nitrogen content increased at the rate of 0.09 percent for each 15 pounds of added nitrogen. Nicotine content increased at the rate of 0.07 percent for each 15 pounds of nitrogen.

Since these experiments have been conducted over a rather limited range of growing conditions, the results are considered preliminary.

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SYMPOSIUM: NEMATOLOGY IN THE TROPICAL AND SUB-TROPICAL ZONES OF THE WESTERN HEMISPHERE

Introduction

A. C. TARJAN[1]

Armen C. Tarjan was born in Cambridge, Massachusetts, on December 10, 1920, attended schools in New York City and Richmond, Virginia, and was awarded a B.S. degree from Rutgers University in 1947. He received the M.S. and Ph.D. degrees from the University of Maryland in 1949 and 1951, respectively. From 1950 to 1951 he was affiliated with the Division of Nematology, Plant Industry Station, United States Department of Agriculture, Beltsville, Maryland as Assistant Nematologist. In 1951 he was appointed Assistant Research Professor of Plant Pathology at the University of Rhode Island. Four years later, he joined the staff at the Citrus Experiment Station, University of Florida, Lake Alfred as Associate Nematologist and was appointed Nematologist in 1958. His major research interests are the systematics, biology, and biological control of plant-parasitic nematodes.

Phytonematology is growing up! From a prolonged infancy characterized by reports of nematode associations with sickly plants, the science was catapulted into childhood mainly by the successful application of the chemical nematode D-D (1,3-dichloropropene 1,2-dichloropropane). The resulting control of plant-pathogenic eelworms commanded attention as did the relatively incidental, though striking, revelation of the insidious and subversive manner in which nematodes can impair crop growth and reduce subsequent yield. The early adolescence of the science was nurtured by the discovery that nematodes are an integral part of certain disease complexes. Phytonematology now approaches adulthood heralded by the revelation that nematodes can act as vectors for other plant pathogens.

The ascent of our discipline onto a more prominent position within the temple of science has not been without tribulation. As phytonematologists we have lamented the exclusion of nematodes from the considerations of some phytopathologists and horticulturists. Yet, as we superciliously wag the critic's finger, can we justifiably claim immunity from the charge of similar negligence boomeranged at us? Has our mental indolence or lack of general training blinded us to the fact that our very existence will be determined by the future progress we make; that in order to advance we must heed the tenets of, and rely on techniques from, other scientific disciplines? Our proper development can occur only when we fully realize the importance of other sciences for interpreting the mysteries of our own—our expansion can come only with their help. This does not at all relegate us to accepting the role of the subservient, but such an approach will

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eventually afford us the necessary stature to stand in equal light alongside our sister sciences.

Despite the relative novelty of plant nematology, we must accept the fact that it is not unique, but actually a branch of parasitology. As such it must not be adulterated with superfluous terminology—designations that are alien to and clash with staid, time-accepted names— unless there is an actual need to coin such new terms. In systematics and nomenclature we have made many mistakes and misinterpretations as a result of our ignorance of developments in allied fields, or as a result of obduracy, but we have not been singular in this respect. The disregard some of us have had for one another's work, depending on whom we studied under, at what institution we trained, or to what country we belong, is hypocrisy of the rankest type. Current trends in our research, exemplified by national and international cooperative effort, indicate that our maturation may be close at hand. With the high quality of personnel our nematology teaching and graduate programs are producing, we can hope for a continued and relentless search for basic facts. Yet, we need not fear the pedantic abandonment of applied or "bread and butter" research, in view of the nationwide acquisition of plant nematologists on agricultural experiment station staffs. Phytonematology is indeed maturing rapidly and the signs for its continued normal growth are most encouraging.

Having considered the current state of our science we now progress from the philosophical to the practical!

When originally approached, over a year ago, to organize a nematology symposium for this Society, I was faced with the decision of either planning for the presentation of a group of papers spanning a broad spectrum of nematological subjects or adapting a program to the specialties of a panel of well-informed speakers. The various nematology workshops and symposia that have been conducted in recent years have usually dealt with nematology in general. Thus it seemed particularly fitting to organize a symposium around the theme of "Nematology in the tropical and subtropical zones of the Western Hemisphere," featuring specialists discussing subjects generally untouched in previous gatherings.

Our speakers, and especially those from outside the mainland of the United States, are to be commended for their willingness to participate in a program that offered no remuneration for personal or travel expenses. It would be remiss of me not to mention that Dr. Fenwick of Trinidad, Dr. Lordello of Brazil, and Mr. del Prado of Surinam expressed their personal regrets at not being able to participate due to the burden of either travel expenses or poor health.

We are indeed fortunate in having Dr. G. Steiner in the role of lead-off speaker, drawing from his vast wealth of nematological experience and setting the pace for the papers to follow.

Note: Dr. Steiner gave a wonderfully fine discussion of the field covered by his paper "Problems of Plant Nematology in the American Tropics." Unfortunately his manuscript was not received in time for inclusion in Proc. Vol. 19. On this account it will appear in a later volume. Ed.

Phytonematology in Panama and Central America

ROGELIO CUELLAR S.[1]

Rogelio Cuellar S. was born in Guatemala, Central America, on August 30, 1923. Although going to elementary school in that country, he later traveled to the United States where he first attended high school in Fullerton, California, and then went to the University of Rhode Island in Kingston. At the latter institution he majored in plant pathology, minoring in nematology and entomology. In 1953 he was appointed Head of the Entomology and Plant Pathology Department, and later Head of the Agronomy Department at the National Institute of Agriculture in Panama. During this time he conducted numerous research experiments on plant diseases, including those caused by nematodes. In 1958 he was appointed Head of the Plant Quarantine Department for the Republic of Panama.

Nematodes, or eelworms, although they include some of our most serious agricultural pests, are a group of organisms little known in Central America. Their microscopic size and the fact that they are generally well hidden, usually in the soil, have obscured their presence from both the general public as well as scientists.

The damage caused by nematodes has frequently been attributed to insects, diseases, lack or excess of water, nutritional deficiencies, and even environmental influences, but very seldom to the true cause.

In Panama, as well as in Central America and many of the other tropical countries, nematodes constitute a group of organisms which are extremely varied in their ecological and physiological activities. For example, some are carnivorous while others are herbivorous. The latter, the so-called plant parasites, may be endoparasitic, living within the plant tissues, or may be ectoparasitic, usually penetrating the plant only with their mouth parts. Some are sedentary while others are migratory parasites. Some are polyphagous while others show a high degree of specialization in the selection of their host plant. There are forms attacking only the roots or other subterranean parts of plants. Others live in stems, leaves, flowers, or fruits of plants; there also are specialized species infecting only seeds.

The effect of nematodes on the plant varies with the severity of attack. If the infection is moderate to severe, the damage to the plants could be characterized by stunted growth, premature ripening of fruit, wilting of parts or, in extreme cases, complete death of the plants. If the attack is light to moderate, the damage is not too noticeable on many plants, except for slight wilting of leaves on dry, hot days.

We have in Central America, as I see it, some of the most complex problems involving plant nematodes. Since it would be impossible to describe all of these problems in this report, I will refer only to the nematode diseases of, and control measures attempted for, some of our principal crops in Panama and Central America.

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COCONUT PALM

The coconut palm is the only cash crop grown on the Atlantic East coast of Panama, as well as in many other coastal areas of Central America. This area is inhabited mostly by Indians who know very little about civilization and, accordingly, almost nothing about the nature of plant diseases.

Natural plantations of coconuts, as well as those planted by the Indians, have, for many years, been suffering from the red ring disease, caused by the nematode *Aphelenchoides cocophilus*. Large numbers of these nematodes attack the roots and trunks of plants creating injured tissues that provide an entrance to many fungi which help to kill the trees in a short time.

Red ring disease is more prevalent and of greater severity in the areas near the Mandinga and Samgande rivers in the San Blas province of Panama. It has been reported not only in Central America but also in South America, viz. Brazil, Venezuela, Colombia, British Honduras, and British Guiana.

The name "red ring" is derived from the symptoms of the disease which appears as a circular band of reddish-brown or red rust color that develops as a ring in the interior of the trunk. This can be seen readily if a cross section is cut in the infected tree trunk.

The leaves exhibit an initial yellowing which gradually turns into brown, accompanied by a withering of the affected blades. These symptoms, however, also occur in palms affected by other adverse factors. Although such coloration generally involves the older leaves, younger leaves are likewise affected when the primary infection occurs higher up the stem. The age and size of palms attacked has varied somewhat in different reports of the disease. In general, however, coconuts are most susceptible from the time they first form a clearly defined stem with a cortex of soft tissue until the time when this cortical tissue hardens.

The period of infection, of course, varies with the conditions under which the palms grow, but in Panama this is generally from the fourth to the seventh year of growth. In Brazil the disease is recorded on palms up to ten years of age.

The red ring forms about two inches from the periphery of the stem, starting as a faint but distinct line around it, and soon developing into a band, 1-1½ inches wide, often colored red-brown to brown rather than red as the name indicates. The nematodes are almost entirely confined to this area of discoloration where they occur in large numbers apparently because of optimum conditions.

Aeration and water supply probably are the factors determining the absence of the nematodes closer to the center of the stem, while the harder tissues confine them from the outside, thus defining the limits of the ring. After the cortical tissues harden they are apparently not favorable for the existence of the nematodes, which probably accounts for the general absence of the disease in older palms. In addition to the discolored areas in the trunk, nematodes may be found generally distributed in the tissues of infected petioles.

It has been observed that this disease is spread by the coconut weevil, *Rhynchophorus palmarum*, that acts as a carrier of infected debris to healthy plants. These coconut weevils are very abundant in Panama which may account for the current rapid dissemination of the disease.

In plantings owned by the Indian populace of Panama, prevailing conditions prevent the application of curative measures when trees are in an advanced state of infection. Affected plants, as well as the primary root system, must be burned in order to destroy the accompanying nematodes and insects.

Although the application of methyl bromide in burned planting sites has been demonstrated to leaders among the Indians, these demonstrations were viewed with apathy, and consequently discontinued.

The problem of infected coconut palm plantings becomes increasingly more acute as production continues to decline.

COFFEE

Central and South American countries, with a few exceptions, extensively cultivate coffee; therefore considerable interest has existed in the diseases of this plant. Lately this interest has been intensified due to a characteristic decline in some coffee plantations which is apparently unaccompanied by a causative fungus or insect. In some instances several trees have died apparently due to this malady. There has been some speculation that the disease may be due to nematodes.

From the discoveries of Bally and Reydon and others, there have been reported 16 different nematodes species that attack the coffee plant. In Central America, however, only eight species have been found, of which only two are known to be extremely injurious to coffee trees.

In many cases, tree decline and subsequent discoloration of leaves have become noticeable in some plantations. After uprooting some of the trees, it was observed that only the primary and secondary roots remained, the tertiary or fine roots having all been almost completely destroyed. *Meloidogyne exigua* was found to be the principal cause of this abnormality. As a result of the death of the fine roots, the absorption of mineral elements by the trees had been affected, eventually causing the expression of symptoms by the trees.

In most Central American countries, especially in El Salvador and Costa Rica, shade trees are interplanted with coffee. The shade trees, which mainly are of the genus *Inga*, have exhibited root knots and partially destroyed root systems. Although the implicated nematode species has not yet been identified, it is believed to be *M. exigua*.

Other nematodes of economical importance attacking coffee are *Pratylenchus coffeae*, and *Radopholus similis*. The latter, which here in Florida causes the spreading decline of citrus, also has been found attacking coffee in El Salvador.

Many other nematodes that attack coffee exist in different countries of Central and South America, but these are of less importance in so far as coffee production is concerned. Some of these, and the countries in which they occur, are:

Aphelenchoides coffeae (Zimm.) —Brazil
Aphelenchoides parietinus (Bastian) —El Salvador
Aphelenchus avenae (Bastian) —El Salvador and Brazil
Ditylenchus procerus (Bally and Reydon) —El Salvador
Helicotylenchus nannus (Steiner) —El Salvador.

There is great variation as far as susceptibility of coffee trees to nematode diseases is concerned. For instance, we have noticed that the *arabica*

and *robusta* species show great susceptibility to nematode attack while *liberica* and *excelsa* seem not to be affected by nematodes. In some instances it has been shown that great differences in susceptibility of coffee exists not only among species but also among varieties, and even individual plants within a variety.

TOMATO

The most important disease of tomato known in Panama, as well as in other countries of Central America, is bacterial wilt, caused by the bacterium *Pseudomonas solanacearum*. This disease, in some fields, causes a loss of from 20 to 100% of the entire planting. Panamanian farmers fear the disease during the entire life of the crop plants. This is prompted by the realization, often gained through bitter experience, that bacterial wilt can kill an entire planting within 2 or 3 days. This is why our farmers are interested in finding out something more about this disease, as well as other factors that increase its incidence and severity.

It is well known, that root-knot nematodes, mainly *Meloidogyne incognita* and *M. javanica*, are limiting factors in the production of tomato, and tomato seedlings in all tropical countries, but especially in Panama. Until recently, crop rotation and the use of newly-cleared land has been the most effective means for their control. Crop rotation, however, has not been completely satisfactory because few crop plants are resistant to root-knot nematodes, and suitable newly-cleared land is becoming scarce in the urban areas or areas near the market.

Thus the necessity of discovering other means of control is indicated. In almost every tomato field affected by bacterial wilt, root-knot nematode has also been found. From the literature as well as by experimentation, we have found that the nematodes are associated with the propagation and dissemination of bacterial wilt. With that idea in mind, four experiments were started at the National Institute of Agriculture in Panama using tomato to determine whether the root-knot nematode creates an opening for the bacteria to enter the plant. The natural consequence of this attack is a rapid, drastic wilt of the plants with the eventual death of the entire planting. It was proved that the nematodes injure the roots of the tomato plants facilitating the entrance of the bacteria into root tissue.

In conjunction with the above tests, investigations were also conducted over a two-year period on the feasibility of using chemical fumigants for controlling the root-knot nematode in tomatoes. These experiments were made at Divisa, in an alluvial soil in which the incidence of root-knot nematodes was high; fumigants were applied 2 weeks before planting. The liquid nematocides either were applied with a hand injector or directly from the original container in a manner insuring delivery of the fumigant at the measured rate. The types of nematocides used and rates of application were: DD (100% active), 30 gal. per acre; Cloropicrin (100%, active), 28 gal. per acre; Ethylene dibromide, 4 gal. per acre; Methyl bromide, 2 lbs. per 100 sq. ft., and Vapam, 10 gal. per acre. There were 4 randomized replications of each nematocide and 8 replications of unfumigated control plots. Nemagon was not used at the time because we were unaware of its existence.

The results indicated a considerable difference, among the five nematocides tested, in their efficiency for controlling root-knot. Only three of the five effectively controlled the parasites. In decreasing order of effec-

tiveness, these were DD, Vapam, and Methyl bromide. Although Ethylene dibromide has been effectively used in the Southern United States, including the State of Florida, it failed to exhibit a similar effect when used in Panama in these tests. One is prompted to wonder whether the humid, hot weather of our country may have been partly responsible. In no case was phytotoxicity in evidence, possibly due to the high water-holding capacity of our soils.

Although *Meloidogyne incognita* and *M. javanica*, were controlled and the incidence of bacterial wilt was reduced through use of chemical fumigants, these were strictly experimental results performed under controlled conditions. On the more practical side, the root-knot nematode continues to spread at such a rapid rate that neither farmer nor horticulturist can materially impede its dissemination. Yet, growers can do much in protecting their investments by planting only healthy, nematode-free seedlings. For this, two fumigations must be performed as follows: (1) in the seed beds prior to seeding, and (2) in the field prior to transplanting.

The first suggested fumigation is feasible but the second, under our present economic status, is prohibited to almost all growers. Thus, even though many growers transplant nematode-free seedlings in the field, such plants may acquire nematode infections in the untreated fields. The lowered productivity of these affected tomato plants is actually more economical than pre-planting fumigation of field soils when one takes into account the low price of only three cents per pound that is paid for cannery tomatoes.

TOBACCO

This crop is new to Panama. In the Chiriqui Province of Panama, there exist several diseases that attack tobacco of which those caused by nematodes are of the greatest economic importance. The root-knot nematode *Meloidogyne incognita*, occupies the most infamous role with respect to its ability to lower the production of choice leaves of tobacco in Panama. *Helicotylenchus sp.* and *Trichodorus sp.*[1] play secondary roles, but are not of lesser importance in tobacco production. Tobacco culture in Panama is gradually increasing in importance, principally due to the establishment, within the country, of several new tobacco processing factories.

The root-knot nematode causes the formation of galls or swellings on the roots of the tobacco plant and is considered the most serious of the three species. It is believed to be present to some extent on almost every farm in the Chiriqui area where flue-cured tobacco is grown. It is also present on many farms in some of the localities where burley tobacco is grown.

There are five species of the root nematodes known to attack tobacco, however, only two of these are present in sufficient numbers on most farms to cause damage to the crop, there are *Meloidogyne* and *Helicotylenchus*.

Pratylenchus, which also has been found in a few cases, cause a girdling of the roots rather than the formation of galls or swellings. As a result of this girdling, brown lesions appear on larger roots, and a high percentage of the fibrous roots are sloughed off. If the *Pratylenchus* attack is severe, the parasitized plants form a restricted, "bunchy" root system. *Pratylenchus* is believed to be present on about 5 per cent of the tobacco farms in the country. At the present time, there are four known species of this

nematodes that attack tobacco; all of these are considered of economic importance.

Although crops such as rice, beans, sugar cane, corn, etc. are cultivated in Panama, research concerning their nematode parasites either has been meager or entirely lacking.

PLANT QUARANTINE

With regard to our own work in Plant Quarantine, we recognize plant pathogenic nematodes to be a real problem about which very little can be done mainly because, our routine plant quarantine inspections are not well adapted to the detection of plant parasitic nematodes. Most quarantine inspections utilize visual examination, supplemented by closer examination with a hand lens or low power microscope, in order to detect the parasitic organisms or to detect symptoms of infection.

Symptoms of nematode injury usually are not diagnostic mainly because they constitute such plant reactions as poor growth, chlorosis and other symptoms equally indicative of root injury from many other causes. Specific symptoms also may vary according to the reaction of different plants to their pathogens.

Examinations for nematodes are usually without value unless laboratory extraction procedures are used and careful identifications are made under high magnification by experienced nematologists, of which, unfortunately, we have very few in Central America.

The only procedure that is being carried on in Panama, as far as entry of nematodes within plants, fruits or seeds, is to try to grow representative samples of these plants or seeds under greenhouse conditions and to study those samples in order to detect any new nematodes coming into the country.

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[1]Identified by J. N. Sasser.

Nematode Problems of the Banana Plant

E. J. WEHUNT
and
Q. L. HOLDEMAN[1]

Estle J. Wehunt received his Ph.D. degree from Louisiana State University in 1958 after studying under Dr. J. P. Hollis and M. J. Fielding. His dissertation was entitled "Nematodes associated with white clover." He joined the research staff of the Division of Tropical Research, United Food Company, La Lima, Honduras, in July, 1958, and has been working on the distribution, identification, pathogenicity, and control of nematodes found on bananas.

The banana plant (*Musa acuminata* Colla) is a large perennial herb propagated from underground rhizomes. The roots are cylindrical, up to half an inch in diameter and twelve feet in length and, except for small feeder roots, are usually unbranched. The vascular portion of the root and rhizome is surrounded by a soft cortex without a corky layer or bark. The absence of this layer leaves the underground part of the plant vulnerable to attack by parasites, particularly nematodes. The nematodes enter the cortical tissue with ease and, if host-parasite relationships are favorable, reproduction and extension of the lesion is rapid.

Root-knot nematodes were the first reported in banana roots in 1883 according to Goodey, 1956 (12). In 1892, a report was made of a nematode disease of bananas in Fiji (1). Cobb (5) described a male nematode believed to be causing the banana disease in Fiji, and in 1915 reported the same nematode in banana tissue from Jamaica and sugar cane roots from Hawaii (6). This nematode is now known as the burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949. Many nematodes have been found associated with bananas since these early reports but most of these are now thought to be non-parasitic to bananas.

The nematodes which attack the banana plant can be placed in four groups, based on their taxonomic sub-families and the symptoms they produce. These groups are:

I. *Pratylenchinae*—Causing deep lesions in root and rhizome.
Radopholus similis (Cobb, 1893) Thorne, 1949.
Radopholus sp.
Pratylenchus coffeae (Zimmermann, 1898) Filipjev and Schuurmans Stekhoven, 1941.

[1]Nematologist and consulting Plant Pathologist, respectively, Plant Pathology Department, Vining C. Dunlap Laboratories, Tela Railroad Company (subsidiary of United Fruit Company), La Lima, Honduras, C. A.

Pratylenchus goodeyi Sher and Allen, 1953.
Pratylenchus sp.

II. *Hoplolaiminae*—Causing shallow lesions in root and rhizome.
Helicotylenchus multicinctus (Cobb, 1893) Golden, 1956.
Helicotylenchus erythrinae (Zimmermann, 1904) Golden, 1956.
Hoplolaimus sp.

III. *Rotylenchoidinae*—Pathology unknown.
Rotylenchoides brevis Whitehead, 1958.

IV. *Heteroderinae*—Causing galls on the root.
Meloidogyne arenaria (Neal, 1889) Chitwood, 1949.
Meloidogyne incognita, var. *acrita* Chitwood, 1949.
Meloidogyne javanica (Treub, 1885) Chitwood, 1949.
Meloidogyne sp.

Group I—*Pratylenchinae*

The nematodes of Group I enter the root cortex or rhizome and, by feeding on and killing the cells, cause a reddish lesion to form. The nematodes and subsequent offspring continue to feed on cell contents causing extension of the lesion which becomes black and shrunken in the older parts while continuing to be red at the advancing margins. Rhizome lesions often extend to a depth of one inch or more. The Pratylenchinae do not feed on vascular tissue; however, other organisms can easily enter the lesion and weaken or kill this tissue, thereby rendering several feet of root non-functional. As a result of the inroads of this group of nematodes, reduction in vigor and growth of the banana plant occurs. Under

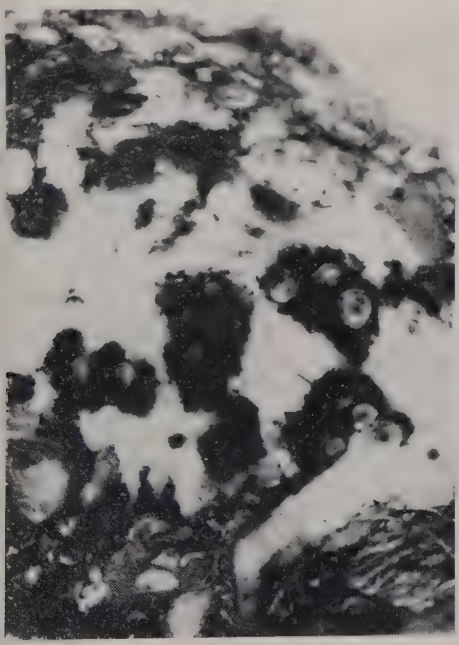

Figure 1.—*Radopholus similis* lesions on rhizome of 'Gros Michel' banana.

Figure 2.—*Radopholus similis* (left) and *Helicotylenchus multicinctus* (right) symptoms on 'Gros Michel' banana roots compared with healthy root (center).

certain conditions, a plant with a badly damaged root system will "tip over" or uproot. Typical symptoms of the attack of nematodes of this group are shown in Figures 1 and 2.

Radopholus similis attacks many different kinds of plants (2). Rating the recorded hosts in order of preference by this parasite, the banana plant is high on the list if the observed reproduction rate of the nematode is considered as the main criterion. *Radolpholus similis* has been reported attacking banana and other *Musa* spp. in Africa (21), Malaya (17), Fiji Islands (5, 6), Australia (6, 8, 20), Jamaica (6, 18), Colombia (3), Panama (19, 23), Honduras (30) and the United States (2, 4, 36). An unidentified species of *Radopholus* was reported from banana in Hawaii (26). Recent surveys by the United Fruit Company in banana plantations of tropical America have revealed that this nematode is present also in Costa Rica, Guatemala, Ecuador, and the Dominican Republic.

Pratylenchus coffeae attacks abaca (*Musa textilis* Nee), plantain (*M. acuminata* X *M. balbisiana*), and banana. The symptoms caused by this nematode are identical to those described for *R. similis*. This is probably also true for other species of *Radopholus* and *Pratylenchus* that attack banana. Microscopic examination is necessary to determine which nematode caused a given lesion. *Pratylenchus coffeae* has been reported on bananas or related *Musa* species in the Philippine Islands (31), Grenada, B. W. I. (7), Honduras (30, 31), Costa Rica (31), Guatemala (31), and Brazil (26). Surveys of the United Fruit Company banana plantings have revealed the presence of this nematode also in Panama, the Dominican Republic, and Colombia. Other species of *Pratylenchus* also have been reported from bananas. An unidentified species was found in Tanganyika, East Africa (35). Goodey (11) reported *Tylenchus musicola* Cobb, 1919 from banana in a greenhouse in England; Goodey's species was later reduced to synonomy with *P. goodeyi* by Sher and Allen (29).

Group II—*Hoplolaiminae*

The nematodes of Group II usually cause shallow lesions in the cortex of larger roots and rhizomes. In small roots, the lesion sometimes extends to the vascular cylinder, with an occasional deep lesion being found in large roots. The first symptoms are black elongated flecks which enlarge, merge and eventually cover the entire root surface. Ruptures in the root surface were reported as a response to the feeding of *H. angustalatus* (35) and have been observed in association with attacks by other members of the *Hoplolaiminae*, but this symptom is not always evident. When the root is split, a wavy lesion is observed, red at the active margin and black in the older portion. Typical symptoms are shown in Figure 2. Nematodes of this group attack the rhizome, causing lesions less than 2 mm. deep which are at first rust colored and later black. This type of lesion differs from the lesion produced by nematodes of Group I by not being shrunken, and being usually shallow.

Helicotylenchus multicinctus has been reported from bananas in the Fiji Islands (5), Australia (8), Cuba (32), and Panama (19). Recent surveys of United Fruit Co. banana plantings have extended the known distribution to Guatemala, Honduras, Costa Rica and Colombia. *Helicotylenchus erythrinae* has been reported attacking bananas in Panama (19) and, in recent surveys, was found in Guatemala, Honduras, Costa Rica and Ecuador. *Helicotylenchus nannus* was reported from soil around bananas

in Honduras (30) but this species has not yet been found feeding on banana root tissue. An unidentified species of *Helicotylenchus* was reported attacking bananas in Colombia (3), while an unidentified species of *Rotylenchus* was reported from soil around bananas in Honduras (30). The latter nematode has not yet been found infecting bananas. *Hoplolaimus angustalatus* was reported attacking bananas in Tanganyika, East Africa (35). Unidentified species of *Hoplolaimus* have been reported from Honduras (30) and Hawaii (28).

Group III—*Rotylenchoidinae*

There are no pathogenicity reports of this group which includes only one species, *Rotylenchoides brevis*, reported attacking bananas in Tanganyika, East Africa (34).

Group IV—*Heteroderinae*

The young root-knot nematodes enter the root at any point and migrate to the cells of the vascular system, where they feed and develop to maturity. If infection is near the root tip, root elongation stops and a terminal gall is formed. If the invasion is farther back from the tip, the root continues to elongate with the development of a swollen area, of varying size, at the infection site. If the invasion is completely separated from the developing tissues of the root, no galling occurs. Mature females are often found in non-galled roots. Invasion of the root tip by large numbers of young nematodes often results in lesions resembling those caused by nematodes of Group I. The tissue dies and has a reddish color while the root often branches after the tip has been thus killed. Typical symptoms of root-knot nematode attacks are shown in Figure 3.

Figure 3.—'Gros Michel' banana roots infected with the root-knot nematode *Meloidogyne incognita*, var. *acrita*.

Meloidogyne incognita, var. *acrita* has been reported from bananas in the Federation of Rhodesia and Nyasaland (22), Peru (15), Panama (19, 23) and Costa Rica (31). *Meloidogyne arenaria* and *M. javanica* have been reported from the Federation of Rhodesia and Nyasaland (22) and *M. arenaria* from Honduras (30) and Panama (19). Unidentified species of *Meloidogyne* have been reported from the Philippine Islands (25), India (27), Egypt (9), Germany (15), and Colombia (3). Recent surveys of United Fruit Company banana plantings have revealed the presence of *M. incognita,* var. *acrita* and *M. arenaria* in Guatemala and Colombia and an unidentified species in the Dominican Republic and Ecuador.

There are several factors that influence the severity of nematode damage to bananas. Soil type plays a major role; nematode populations are generally higher and damage greater in sandy soils than in clay soils, providing moisture is adequate. Stover and Fielding (30) reported fewer numbers of *Radopholus similis* from clay loam than from sandy soil. Hughes (13) reported less burrowing nematode damage on citrus plants growing in soils high in clay. In field observations, drainage, soil moisture, and soil structure are factors that affect fluctuations of nematode populations.

Nematode damage to the banana plant was considered of minor importance in the past; however, within recent years much attention has been given to this damage, especially that caused by *R. similis.* Vilardebo (33) reported up to 50% increase in yields when nematodes were controlled by soil fumigation. In Australia, *R. similis* is considered a serious pest and plans have been made for chemical fumigation of large field experiments following results of pot experiments (20). Leach (18) reported Blackhead disease to be serious, and studies are under way in Jamaica. Venning (32) believed that nematodes were responsible for the decline of the banana industry in Cuba. Newhall (22) and Loos (19) reported some relationships between *Fusarium* wilt of bananas and root-knot and burrowing nematodes.

There are reports of differences in susceptibility of banana varieties to *R. similis.* Nowell (24) reported the 'Chinese' and 'Silk Fig' banana to be affected less than the 'Bluggoe' banana. Leach (18) reported the 'Lacatan' variety in Jamaica to be much more susceptible than the 'Gros Michel' to Blackhead disease caused by *R. similis.* Venning (32) reported the 'Lacatan' more susceptible than 'Gros Michel' to attack by *H. multicinctus.*

In 1892, Cobb and von Mueller recommended plow fallow or crop rotation plus the use of clean rhizomes or "seed," for the control of the nematode disease of bananas in Fiji (1). Cobb recommended the trimming away of all discolored portions of the rhizome to achieve nematode free "seed." Illingsworth in 1920 (14) reported on work by A. H. Benson on trimming away the lesions and then dipping the trimmed rhizome in mercuric chloride solution prior to planting in order to eliminate nematode infestation. Godfrey in 1932 (10) recommended rhizome trimming followed by a hot water dip to eliminate nematode infestation from bulbs of the edible cana (*Canna edulis* L.). Loos (19) recommended trimming away the lesions, followed by a hot water dip or immersion in Dithane D-14 for one minute and a mixture of Bordeaux and Nemagon for one minute to eliminate nematode infection from banana rhizomes and reduce rhizome rot.

In the United Fruit Company, research is underway to find economical and practical nematode control measures. The most important measure in practice at present is prevention, i.e., planting nematode-free rhizomes

or "seed" in new lands or former plantations now being replanted. Two closely related "clean seed" programs are underway: 1) a "certified seed" program in which a few seed are pared to remove visible nematode lesions, dipped for 10 minutes in water at 55°C., planted in sterilized soil, and inspected at several stages while the seed is being increased, and 2) an "improved" seed program in which all seed are pared, dipped for 1 minute in 1% Dithane D-14 and then dipped for 1 minute in 25-25-100 Bordeaux mixture to which Nemagon has been added at 1:1000 concentration. The Dithane is added to reduce surface contamination of *Fusarium oxysporum* f. *cubense;* the Bordeaux mixture is used to reduce incidence of bacterial rhizome rot. Both programs are aimed at eliminating all seed-borne diseases and pests, including nematodes. The "improved seed" is used for immediate planting needs; "certified seed" is for gradual development of truly pathogen-free plantings.

Several measures can be used to reduce nematode populations in the soil. Soil fumigation, the most widely used, is expensive. Its advantage is that there is little or no interruption in banana production when the fumigant is applied to soil in which bananas are growing. Rotation with non-host crops causes reduction by starving the nematodes or by depriving them of an environment suitable for reproduction. The disadvantages of this method include the expense of the alternate crop and the loss of banana production during its growing period. Flooding of the soil for prolonged periods of time prevents growth of host plants and reduces the nematode population by starvation. The disadvantages are obvious; not all land can be flooded, flooding is expensive, and banana production is lost. Dry fallowing has been used to advantage with crops other than bananas, but again there is a prolonged loss of production.

It is evident that further intensive research is required before firm conclusions can be drawn or strong recommendations made on the nematode problems in banana production.

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Observations on Some Subtropical Plant Parasitic Nematodes in Florida[1]

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Leon G. van Weerdt was born at Boxtel, the Netherlands, on September 12, 1929. He received a "Candidaats" degree from Wageningen University in April 1954, having majored in Chemistry and tropical agriculture. In May of 1954 he came to the United States and after four months' training with the Waverly Growers Citrus Cooperative, entered the University of Florida where he pursued graduate studies in Plant Pathology. He received the Master of Science degree in February 1956 and accepted the position of Assistant Nematologist with the State Plant Board of Florida, working under Dr. B. G. Chitwood. During this same period he continued his education toward a Ph.D. degree at the University of Florida, with a major in Nematology and a minor in Biochemistry. The Ph.D. degree was granted in February 1959. At this time Dr. van Weerdt was appointed Chief Nematologist with the State Plant Board, succeeding Dr. Chitwood, who had resigned from this position earlier. Dr. van Weerdt's main research interests are: embryonic and post-embryonic development of nematodes and nematode anatomy and physiology.

1. THE BURROWING NEMATODE, *RADOPHOLUS SIMILIS* (COBB, 1893) THORNE, 1949.

Suit and DuCharme (1953) showed that the burrowing nematode is the cause of Spreading Decline of Citrus. The State Plant Board of Florida maintains as one of its activities a continuous program designed to contain the burrowing nematode within the boundaries of the areas known to be infested. Part of this program involves keeping the host list of this nematode up to date. Plants not known to be hosts but found to be infected by the nematode as a result of routine inspections of plant propagating nurseries, are immediately added to the host list. In addition, whenever the need arises, plants are tested for their susceptibility to attack by burrowing nematodes through inoculation experiments in the greenhouse.

Plants to be tested were established in six replications in *Radopholus similis* infested soil from a Spreading Decline grove. Moreover, a suspension of burrowing nematodes, obtained by incubation (Young, 1954) of infected citrus roots was added to the soil. Corn (*Zea mays* L.) var. Golden Bantam plants were treated like the plants under investigation and served to check the viability of the inoculum. The plants were removed eight to twelve weeks after inoculation and their roots incubated and dissected. When burrowing nematodes were recovered from the roots

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following incubation, and the nematodes and their eggs were dissected out of the roots, the plant was considered a host plant. The following plants were established as hosts in this manner, and these records are believed to be new: Australian pine (*Casuarina equisetifolia* L.); Bullhorn acacia (*Acacia cornigera*); Coffee weed (*Emelista tora* (L.) Britton & Rose); Swamp mahogany (*Eucalyptus robusta* Smith); Cluster fig (*Ficus glomerata* Roxb.); Jambolan plum (*Syzygium cumini* Skeels); Punk tree (*Melaleuca leucadendra* L.); Ceriman (*Monstera deliciosa* Liebm.); Loblolly pine (*Pinus taeda* L.); Pecan (*Carya illinoensis* Koch.); Soybean (*Glycine* Max Merr.) and Strawberry (*Fragaria hybrid*).

Although tests such as those above failed to show that Queen's Palm (*Arecastrum romanzoffianum* Becc.) was a host, this palm was found heavily infected by burrowing nematodes under natural field conditions in two different localities in Florida. Therefore, Queen's Palm was added to the host list. Thus it is indicated that plants which escape infection following inoculation cannot necessarily be regarded as non-host plants. Some of the difficulties involved in trying to establish host plants of burrowing nematodes by artificial inoculation have previously been discussed (DuCharme and Birchfield, 1956; van Weerdt, 1957).

The burrowing nematode was recently recovered from Key West, Florida, from around the roots of *Cocos nucifera* L. Examination of soil samples from coconut palms in Jamaica also revealed a few burrowing nematodes. *Melaleuca leucadendra* roots growing in heavy muck soil in West Palm Beach, were found to be heavily infected with *Radopholus similis*. This is considered an unusual habitat for burrowing nematodes.

Since 1956 the Neanthe bella palm (*Collinia elegans* Liebm.) has been

Figure 1. Left: Neanthe bella palms severely infected with burrowing nematodes. Right: A palm of the same age only very slightly infected.

listed as a "probable host," meaning that the presence of the nematode was revealed by routine laboratory procedures but the parasite was not actually dissected out of the roots. Recently two cases were encountered where several thousand Neanthe bella palms, growing under shade, were found to be heavily infected with *R. similis*. Severely damaged, heavily infected palms (Figure 1, left) were stunted, chlorotic and spindly. The root system was very sparse with only a few stubby roots left and a total absence of feeder roots. Slightly infected palms (Figure 1, right) of the same age were considerably taller, but also spindly and chlorotic. The root system was under-developed and the plants were lifted easily from the soil.

When the stems of heavily infected plants were split longitudinally, it was noticed that the basal portion of the stems were rather dry, necrotic, and showing a reddish-brown discoloration. An abundance of burrowing nematodes was found inside the *stems* at the junction of diseased and healthy tissues, one to two inches above the ground (Figure 2). The above symptoms were not specific for burrowing nematodes, however, since one case was found where lesion nematodes (*Pratylenchus* sp.) caused a very similar syndrome on *Collinia elegans*.

Tests in Apopka, Florida, have shown that drenches of DBCP (Nemagon) at the rate of 4 gallons of the active ingredient by volume per acre, are very phytotoxic to the roots of these palms, resulting in a severe stunting of the plants.

2. THE CITRUS NEMATODE, *TYLENCHULUS SEMIPENETRANS* COBB, 1913.

Chitwood and Birchfield (1957) reported the citrus nematode as native to Florida. This view was recently confirmed by the recovery of citrus nematodes from soil around the roots of coconut palms growing in non-cultivated and apparently virgin soil along the shores of Greyhound Key in the Florida Keys.

Dr. Birchfield has developed a chemical dip for the control of citrus nematodes on citrus nursery stock. Ten bare-rooted rough lemon seedlings, heavily infected with citrus nematodes were dipped in each of the following:

(1) Diethylpyrophosphate (TEPP-40) at the rate of ⅛, ¼, and ¾ gallon of the commercial material (40 percent by weight of active ingredient) per 100 gal. of water, for an instant, one-minute and five-minute time intervals.

(2) 1,2 dibromo-3-chloropropane (DBCP or Nemagon-50) at the rate of 14 ml. and 42 ml. of the commercial material (73.3 percent by weight of active ingredient) per 5 gallons of water for an instant, two-minute and five-minute time intervals.

(3) O, 0 diethyl-O-p-nitrophenyl thio-phosphate (parathion) at the rate of 1, 3, and 6 pounds of the commercial material (42 percent by weight of active ingredient) per 100 gallons of water for an instant, one-minute and five-minute time intervals.

(4) 0-2-4-dichlorophenyl O, O-diethyl phosphorothioate (VC-13) at the rate of ¼, ½, and 1pint of the commercial material (75 percent by weight of active ingredients) per 5 gallons of water for an instant, one-minute and five-minute time intervals.

Figure 2.—Neanthe bella palms, heavily infected by burrowing nematodes, showing severely reduced root systems. The stems have been split longitudinally revealing the brown discoloration of the basal portion of the stems.

After treatment the seedlings were potted separately, placed in the greenhouse, and examined after 3 and 6 months. The results showed that:

Diethylpyrophosphate was very phytotoxic to the citrus seedlings under the conditions of the experiment.

Parathion was not objectionably phytotoxic, but did not destroy the citrus nematodes.

VC-13 was not phytotoxic but its effect on citrus nematodes was some

what erratic. This material showed promise, however, and may warrant continued investigation.

DBCP (Nemagon-50) at 14 ml. per 5 gallons of water for an instant, 2 minutes and 5 minutes, and at 42 ml. per 5 gallons of water for an instant and 2 minutes did not destroy the citrus nematodes. However, DBCP at 42 ml. per 5 gallons of water for 5 minutes destroyed not only the citrus nematodes but also their egg masses which failed to bring about an infection of healthy roots upon addition of the treated roots to the soil around the healthy seedlings, indicating ovicidal as well as nematicidal value.

A *drench* of DBCP containing 42 ml. (Nemagon-50) per 5 gallons of water proved lethal to rough lemon seedlings.

3. KIDNEY-SHAPED NEMATODES, *ROTYLENCHULUS* SPP.

A. The Reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940. The reniform nematode was found parasitizing roots of mango trees (*Mangifera indica* L.) on the grounds of the University of Florida Subtropical Experiment Station at Homestead, Florida.

B. A kidney-shaped nematode, *Rotylenchulus* (n.sp.), as yet undescribed, was found wide spread through southern Florida. This nematode is very similar to the reniform nematode. The male of this new species lacks caudal alae, however, and the male and female fourth-stage larvae are quite different from each other. The male fourth-stage larva has a weak stylet, similar to that of the mature male; its median bulb is reduced in size with valves almost absent. The female fourth-stage larva, on the contrary, has a strong stylet and a large median bulb with conspicuous valves.

This kidney-shaped nematode is very similar to *Spirotylenchus queirozi* Lordello & Cesnik, 1958, also showing the phenomenon of sexual dimorphism in the larvae.

In soil samples only larvae, males and young females were encountered. These young females were slender, eel-like nemas resembling the fourth-stage female larva in size and general form. The vulva was not prominent and the ovaries were undeveloped. Often soil samples were found teeming with hundreds of these nematodes with no, or very few, other plant parasitic nemas present.

Since most of our records were obtained by sampling nursery beds, which had been kept scrupulously clean of weeds and foreign plant material, the plants being propagated in the beds could be considered, almost with certainty, to be the host plants of these nemas. However, in spite of the large number of males and young females in the soil, only once was a slightly swollen, more mature female dissected from roots.

Inoculation experiments in the greenhouse, by adding 100 specimens (larvae, males and young females) to the soil around a bean plant (*Phaseolus vulgaris* L.), showed a two- to threefold increase in the number of specimens over a three-months period. But, here again, in spite of extensive searching, and staining, only once a swollen female with well-developed gonads was found semi-endoparasitically on the roots.

Minton and Hopper (1959), reporting the parasitism of *Rotylenchulus reniformis* on cotton in Alabama, did not observe swollen females on the cotton roots in the field. However, swollen females were recovered from cotton roots following inoculations under greenhouse conditions.

Plants, around the roots of which large numbers of *Rotylenchulus* n.sp. were recovered in southern Florida and the Florida Keys, include: *Acanthus mollis* L., *Arecastrum romanzoffianum* Becc., *Carica papaya* L., *Caryota mitis* Lour., *Caryota urens* L., *Citrus mitis Blanco*, *Croton* sp., *Cocos nucifera* L., *Hemerocallis* sp., *Opsiandra maya* O. F. Cook, *Paurotis wrightii* (Griseb. & Wendl.) Britton, *Phoenix reclinata* Jacq., *Phoenix* sp., *Ptychosperma elegans* Blume, *Raphiolepis* sp., *Roystonea regia* O. F. Cook, *Sabal palmetto* Lodd., *Washingtonia* sp., and *Zoisia* sp.

Rotylenchulus (n.sp.) was also recovered from soil samples collected in citrus groves in Jamaica. The possible role of these kidney-shaped nematodes in the "Lethal Yellowing" disease of coconut palms has been discussed elsewhere by van Weerdt, Martinez and Esser (1960).

4. PLANT-PARASITIC NEMATODES ASSOCIATED WITH COCONUT PALMS.

Following is a list of plant-parasitic nematodes recovered from soil samples collected around the roots of *Cocos nucifera* L. in Key West and West Palm Beach, Florida: *Aphelenchoides* n.sp.; *Belonolaimus longicaudatus* Rau, 1958; *Cacopaurus* (n.sp.); *Criconemoides citri* Steiner, 1949; *Criconemoides mutabile* Taylor, 1936; *Helicotylenchus erythrinae* (Zimmermann, 1904) Golden, 1956; *Hemicriconemoides cocophilus* (Loos, 1949) Chitwood & Birchfield, 1957; *Hemicriconemoides wessoni* Chitwood & Birchfield, 1957; *Hemicriconemoides structathecatus* Esser 1960; *Hemicycliopthora* sp.; *Heterodera* spp.; *Hoplolaimus tylenchiformis* v. Daday, 1905; *Meloidogyne* spp.; *Paratylenchus minutus* Linford in Linford, Oliveira & Ishii, 1949; *Pratylenchus brachyurus* (Godfrey, 1929) Filipjev & Schuurmans Stekhoven, 1941; *Pratylenchus hexincisus* Taylor & Jenkins, 1957; *Radopholus similis* (Cobb, 1893) Thorne, 1949; *Scutellonema* (n.sp.); *Trichodorus christiei* Allen, 1957; *Trichodorus proximus* Allen 1957; *Tylenchorhynchus* sp.; *Tylenchulus semipenetrans* Cobb, 1913; *Xiphinema* (n.sp. according to A. C. Tarjan); *Xiphinema americanum* Cobb, 1913.

Aphelenchoides cocophilus (Cobb, 1919) Goodey, 1933, was obtained from coconut palm material sent in from Trinidad, but has not been encountered in Florida.

5. SESSILE NEMATODES, *CACOPAURUS* (N.SP.)

Sessile nematodes were first reported from Florida as *Cacopaurus* sp. by Esser (1957). Since then sessile nemas have been recovered from various localities in the State, ranging from Jacksonville in northeastern Florida to Canal Point in South Florida.

A close comparison of the Florida specimens with the two described species from California, *Cacopaurus pestis* Thorne 1943, and *Cacopaurus epacris* Allen and Jensen, 1950, showed that Florida specimens belonged to a species as yet undescribed. The absence of minute tubercles on the cuticle, the long attenuated tail and the rather sudden diminution of the body diameter in the neck region of the female are distinguishing characteristics. *Cacopaurus* n.sp. was recovered from the following hosts: *Celtis laevigata* Willd.; *Polystichum adiantiforme* J. Smith; *Carya glabra* (Mill.) Sweet; *Cocos nucifera* L.; *Euonymus japonicus* L.; *Liquidambar styraciflua* L.; *Taxodium distichum* Rich; *Saccharum officinarum* L.; *Magnolia grandiflora* L.; *Juncus* sp.; *Panicum* sp.; and *Pinus elliottii*, Engelmann.

6. ROOT-KNOT NEMATODES, *MELOIDOGYNE* SPP.

A. The Southern root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949.

Stem sections of clock vine (*Thunbergia grandiflora* Roxb.) showing enormous galls were submitted to the laboratory for diagnosis on various occasions. The tumors had been collected from vines at Coral Gables, Naples, Vero Beach, Tampa, and St. Petersburg, indicating a rather wide distribution of the disease in southern Florida.

The size of the galls varied from about six inches to approximately two feet in diameter (Figure 3). Sometimes they were located at the basal part of the stems touching the ground, in other instances they occurred two to three feet above ground.

Dissection of the cankerous tissues revealed an abundance of root-knot nematodes in all stages of development. However, a bacterium, in culture closely resembling *Agrobacterium tumefaciens* (E.F.Sm. and Town.) Conn., was also found in the young gall tissues in those cases examined for this purpose. This brings up the interesting question as to which organism initiated the gall. It is quite possible that the bacteria caused the tumor and that the cankerous tissues attracted the nematodes.

B. The grass root-knot nematode, *Meloidogyne* (n.sp.?).

Lately several cases have been encountered in which grass roots (*Stenotaphrum secundatum* Kuntze) were severely infected by root-knot nematodes, causing a marked yellowing and a general decline of infested lawns. Infected roots showed no knots or galls but only an occasional, slight

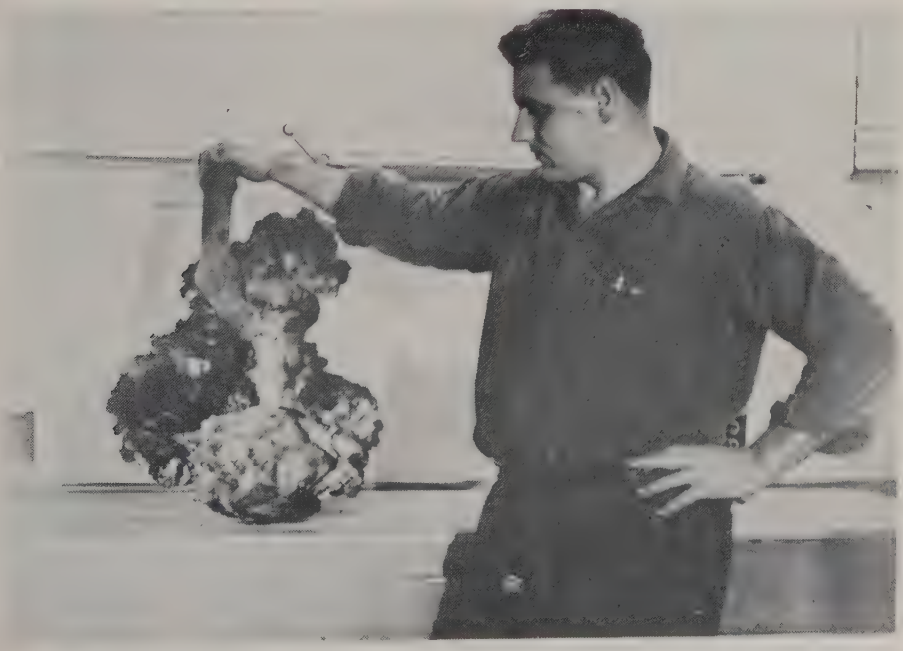

Figure 3.—Stem section of *Thunbergia grandiflora* with large gall containing enormous numbers of root-knot nematodes.

swelling of the root at the point of attack. Mature females protruded conspicuously from the roots with only the head and neck embedded (Figure 4). The eggs were deposited, partly inside the female body and partly in a gelatinous matrix attached to the posterior part of the nematode.

Optical sections of mature females showed the body wall as a thick but hyaline capsule (Figure 4, right center). The vulva and anus were located on a slight protrusion of the body (Figure 4, right bottom). The perineal pattern of the female resembled that of *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949. However, the transverse striations in the perineal region were not completely interrupted on each side of the body by a longitudinal groove as in *M. javanica*. Instead, the lateral lines blended harmoniously with the striations in the perineal region, creating deeply constricted folded annules. This peculiar pattern may have been the result of the protrusion of the body in the perineal region.

Females were broadly oval in shape, with the neck and head located to one side of any median plane through the protruded vulva. The semi-endoparasitic mode of life is possibly responsible for the asymetric development. The larval tails were not sharply attenuated as in *M. javanica* but conoid as in *M. incognita*. The rectum of the larvae was dialated as illustrated by Chitwood (1949) for *M. incognita*. All males studied were true males, and no intersexes were observed.

7. DAGGER NEMATODES, *XIPHINEMA AMERICANUM* COBB 1913.

Clumps of bamboo (*Bambusa* sp.) in a private garden in Miami and in the U.S.D.A. Plant Introduction Garden showed signs of decline. The

Figure 4.—Root-knot nematode females protruding from the roots of St. Augustine grass. Note the thick body wall in optical section (right, center) and the slight protrusion of the body in the perineal region (right, bottom).

young shoots did not develop properly and died when they were only two to three feet long. Soil samples revealed the presence of huge numbers of *Xiphinema americanum* in both cases.

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Mr. Ray Long, State Plant Board Inspector, collected the soil samples from around coconut palms in the Palm Beach area. Mr. Howard van Pelt, State Plant Board Inspector, carried out the chemical control experiments in the Apopka area. Dr. E. B. Sledge, Nematologist, State Plant Board, collected the root-knot nematodes on St. Augustine grass. Mr. Jerry Messec, State Plant Board photographer, took the photographs.

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The Possibilities of Biological Control of Plant-Parasitic Nematodes in Tropical and Sub-Tropical Areas

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William A. Feder was born in New York City on October 15, 1920. He received a Bachelor of Arts degree from The John Hopkins University in 1941 after which he served as an officer in the U. S. Navy in the Pacific during World War II. Returning to civilian life he enrolled at the University of California at Berkley, receiving a Ph.D. degree in Plant Pathology in 1950. From 1950 to 1951 he was affiliated with the University of Hawaii as Storage Disease Pathologist and Nematologist. Returning to the United States, he was appointed Associate Professor of Plant Pathology at Cornell University and served in this capacity from 1951-1954. In 1954, he joined the Agricultural Research Service, Crops Research Division, U. S. Department of Agriculture in Orlando, Florida, as Pathologist and Nematologist which is his present status. From 1958 to 1959 he was the recipient of a National Science Foundation Senior Post Doctoral Fellowship and spent this period at London University, the Polytechnic, working with Dr. C. L. Duddington on various basic aspects of the biological control of nematodes with predaceous fungi. Dr. Feder's work involves the nematodes affecting growth of citrus trees, with special emphasis on the biological control of these nematodes as well as the development of nematode-tolerant or resistant citrus rootstocks.

According to current information, about 2/3 of the world's population is still hungry. This fact, coupled with the tremendous population increase in the last 50 years, means that agricultural production must be greatly increased in many areas where it is now marginal or even submarginal. Since the factors affecting distribution are difficult to regulate, at least currently, it is incumbent upon various countries with large populations to increase their agricultural productivity. Agricultural productivity is a composite of soil fertility, disease and pest control, and general agricultural know-how.

It is becoming increasingly evident that nematodes cause huge losses of agricultural crops all over the world. Historical studies clearly indicate that nematode problems have been troubling the agricultural world for hundreds of years. It is only in the last 20 or 30 years that any degree of control of plant-parasitic nematodes has been achieved, but these achievements have been small indeed, when compared with the amount of the earth's surface now under cultivation. For years, crop rotations have been practiced as a way of avoiding soil-borne diseases and pests. For the past 2 decades, soil fumigation has revolutionized agriculture in certain small areas, especially in the United States and Western Europe. Soil fumigation to control nematodes attacking annual crop plants has become a common practice in many of the agricultural areas of the United States. However, soil fumigation as practiced with such high-value crops as tobacco, certain

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ornamentals, etc., is far too expensive to be carried out on a large scale in many of the agricultural areas of the world. The chemicals and application equipment are expensive. In addition, the difficulties and complexities involved in using these chemicals make it extremely difficult for them to find favor in the countries of Asia and Africa, where many people are still unable to read and write. Further, few of these chemicals are of use for control of nematodes on tree crop plants and other perennial plants because of their high phytotoxicity. This does not, of course, mean that chemical control of plant-parasitic nematodes and other soil-borne pests and diseases is not practical and will not be practiced by ever-increasing numbers of farmers all over the world where the economics of the crops permit. The search for non-phytotoxic nematocides must be continued. However, in certain areas we must look for alternatives to chemical control; to alternatives which are cheaper, which are easier to use, and which can be more readily understood by the farmers using them.

What ways are then open to us? There is, of course, the possibility of breeding for resistance or tolerance to nematodes and to soil-borne diseases and pests, and this has been done in some cases quite successfully. In addition, crop rotation can be practiced very successfully in some cases. There is still another method which has lured entomologists and plant pathologists for some time. This is biological control, which may be defined as the use of a living organism to destroy a pest (18). Biological control of insects has received considerable attention in the last 15 or 20 years and has met with some small amount of success in certain cases. The control of the cottony cushion scale, the introduction of milky disease of Japanese beetle, and the recent work of Dutky on moths are a few examples of successful biological control of insects (19). What then may be expected in the way of success for biological control of nematodes? In the words of Garrett, "Root disease investigators have before them the elusive lure of biological control—" (22). How elusive is this lure, and on what basis do we have any grounds for optimism for the success of biological control of nematodes?

The present paper attempts to give a background of what is already known about the interrelationships between nematodes and various other soil micro-flora and fauna and gives a resume of some of the practical accomplishments in attempting to use various microorganisms to control the activities of plant-pathogenic nematodes.

Obviously, nematodes form a part of the vast and complex dynamic equilibrium which functions in all living soils. The nematodes with which we concern ourselves as plant nematologists are those which have developed the parasitic habit and are capable of obtaining their food from the roots and other parts of living plants. These nematodes, however, do not function in a vacuum but must live and compete amongst the total soil microflora and fauna. The competition at the root surface must be fierce. Nematodes, bacteria, fungi, and various insects, as well as protozoa and a myriad of other forms, are busily competing for various defined nutrients and growth factors which the plant is eliminating into the soil as it metabolizes. The nematode working its way into the cortical regions of a root is also excreting metabolites which various other microorganisms are capable of utilizing. Thus, nematodes may attract to them various types of fungi and bacteria which are capable occasionally of penetrating the waxy cuticle of a nematode or entering the nematode through other openings and becoming parasitic upon the nematode.

As early as 1888, Zopf (33) was able to demonstrate that a certain fungus was capable of actually capturing living nematodes and feeding upon their body content. This is probably the first description of a so-called predaceous fungus. Zopf's studies were followed up to a limited extent over the next 30 or 40 years by numbers of mycologists and others who gave brief and often inaccurate descriptions of various nematode-capturing fungi and pictured what appeared to be bacterial and sporozoan diseases of nematodes (15). However, it was the work of Charles Drechsler, beginning in the 1930's and carried on at a rapid pace for the next 20 years, which gave some definition and concept to the range of numbers and activity of the predaceous fungi. Drechsler's detailed and painstaking descriptions of the various predaceous fungi which he came across in his studies now form a classical basis for the systematic study of this group of organisms. They give a taxonomic background which aids in delineating these organisms. They also give some concept of the range of devices used for capturing nematodes which we can expect to encounter in natural soils. He has laid the groundwork for a better understanding of this whole group of unique organisms. Others such as C. L. Duddington and his students have added considerably to our taxonomic and ecological knowledge of these nematode-capturing fungi.

Because of the flamboyant manner in which these organisms capture nematodes, much attention has been paid to them, almost to the exclusion of other microorganisms which may be attacking nematodes, but which are more difficult to observe and manipulate. Thus, much study has gone into the mechanisms controlling constricting ring development, the opening and closing of the ring, and the various materials capable of stimulating ring formation. To date, all attempts to control nematodes on a field scale have been made by using various members of the predaceous fungi.

It should, however, be pointed out that there is another group of nematode-attacking fungi which are endozoic in habit. These organisms, instead of capturing the nematodes with loops, knobs, and other devices, simply penetrate the cuticle or grow in through natural openings or are swallowed by the nematodes and proceed to germinate and infect the nematode from within and eventually utilize all the body contents. The nematode soon dies and the fungus then sporulates and the cycle is repeated. These organisms have been given little recognition from a practical point of view because of the difficulty in cultivating them and manipulating them. It is only recently that one of them, *Harposporium anguillulae* Lohde has been cultured in artificial media (1).

There are also many sketchy records of apparent bacterial infections of nematodes and some records of sporozoan infections of nematodes. Because micro-techniques have yet to be worked out for handling these organisms, no work, descriptive or for control purposes, has been done utilizing these organisms. They are essentially uncharacterized in the literature. There is also clear-cut evidence that certain soil insects and mites are capable of feeding upon active, free-living nematodes, but no thorough-going investigation of these forms has been made (15). Finally, it is recognized that certain nematodes feed on other nematodes. This fact has been known for many years, and limited attempts have been made to use these organisms in a biological control program (15).

I shall now give a general description of the more common forms of the predaceous fungi, and then I shall discuss some of the attempts to control nematodes with these fungi. The predaceous fungi that attack

nematodes can be divided into 3 distinct groups—the Zoopagales, the nematode-trapping Hyphomycetes, and endozoic Hyphomycetes. Of these, the first and last are obligate predators, without distinctive morphological adaptations to the predaceous habit, while the predaceous Hyphomycetes are faculative saprophytes and are provided with highly specialized organs which enable them to capture nematodes alive. The Zoopagales is an order of Phycomycetes preying mainly on amoebae and other protozoa, but it contains a few species that capture nematodes: for example, *Stylopage hadra* Drechsler (9), *Stylopage leiohypha* Drechsler (10), and *Euryancale sacciospora* Drechsler (12). The nematode-trapping Hyphomycetes are a group of imperfect fungi remarkable for the morphological adaptations that enable them to trap their prey: for example, *Arthrobotrys oligospora* Fres., *Dactylella ellipsospora* (Preuss) Grove, *Dactylella bembicodes* (11), *Dactylella doedycoides* Drechsler (13), and many others. The endozoic Hyphomycetes, which are internally parasitic in nematodes, attack them usually by means of sticky spores: for example, *Harposporium anguillulae* Lohde (24); *Acrostalagmus obovatus* Drechsler, *Nematoctonus leiosporus* Drechsler (13), and a number of others.

Members of all these groups have been found in soils in such divergent places as pineapple fields in Hawaii, peat bogs in Lapland, and glacial refuse in Denmark, various parts of England and Scotland, and areas as far north as New York and Massachusetts in the United States and as far south as Florida. Thus representatives of these organisms are widespread in nature and are capable of living in soils which vary greatly in temperature, soil moisture, and type. *Stylopage hadra* is common and widespread and has been recorded from Hawaii and the United States as well as from Great Britain. The surface of the mycelium of this organism is sticky, and if a nematode happens to come in contact with it, the nematode is caught like a fly on flypaper. Under natural conditions the sticky secretion appears to be adhesive only for nematodes. When the nematode has been captured the fungus forms a bulbous outgrowth at the point at which the animal is held, apparently an appressorium, for a further outgrowth from it penetrates the integument of the animal which is by this time moribund. The penetration branch then gives rise to a system of haustorial filaments which spread throughout the body of the animal and absorb its contents. The capture of a nematode is followed by great cytoplasmic activity on the part of the fungus (2) which may be connected with the secretion of the sticky fluid by which the prey is held; the fluid is produced in large quantities and is easily visible under the microscope. Absorption of the body contents of the nematode is very complete, so that in the end only the shrivled integument, filled with hyphae, remains. In laboratory cultures, reproduction of the fungus usually begins after a preliminary feeding period; large, pear-shaped aerial spores are formed at the apices of erect fertile hyphae that rise to a height of upwards of half a millimeter above the subsurface of the substratum.

Among the nematode-trapping Hyphomycetes are a number of different types of trapping organs or organs of capture. Some of the traps are adhesive, working on the flypaper principle; others are purely mechanical in their action. Both kinds of traps are extremely efficient, at least under laboratory conditions, and the sticky traps especially show a remarkable range of morphological diversity. The commonest form of trap is the adhesive network formed by a number of Hyphomycetes belonging to the genera *Arthrobotrys, Trichothecium, Dactylaria,* and *Dactylella.* A lateral

branch from the mycelium of the fungus curls around and returns to the main hyphae anastomsing with it. Other similar branches arise either from the first one or from one near it so that the complex system of mycelium is formed. As the individual loops have a strong tendency to form at right angles to one another, the result is a three-dimensional network, with many of the loops standing up perpendicularly like wickets. Like the mycelium of *Stylopage hadra*, the networks are highly adhesive for nematodes, which are caught and held upon contact. Destruction of nematodes by these Hyphomycetes may be very great and in cultures many dead and dying nematodes are visible to the naked eye. When a nematode is captured it struggles violently for a time, but its movements gradually become feebler until it is quiescent; by the end of 2 to 4 hours the animal is moribund, if not dead, and a narrow branch from the point of contact with a loop that holds it penetrates the integument of the animal. The infection branch then swells within the animal, forming a bulbous structure, the infection bulb, from which trophic hyphae grow out and fill the body of the animal, gradually absorbing its substance so that eventually only the empty skin is left filled with trophic hyphae; and when their work of absorption is completed, these too lose their contents.

Instead of having adhesive networks, some of the predaceous Hyphomycetes possess sticky processes by which nematodes are caught. In *Dactylella cionopage* (14) short, one-celled rather pointed processes give the mycelium a spikey appearance under the microscope; these processes are sticky and capture the eelworms in the same manner as the networks already described. When an animal has been captured, the intrusion of an infection bulb giving rise to trophic hyphae proceeds as in the reticular species. The adhesive processes are unicellular when young, but later they increase in length, become multicellular, and may develop into somewhat irregular networks which, however, never obtain the degree of complexity found in the true reticulate forms. From the adhesive processes of *Dactylella cionopaga* and *Dactylella lobata* Duddington, it is a logical step to the adhesive knob, such as is found in *Dactylella ellipsospora* (Preuss) Grove (11). The organ of capture here is a subspherical knob attached to the mycelium by a short, usually two-celled stalk. Nematodes are captured by adhesion to the knobs.

In addition to the adhesive organs there are 2 kinds of purely mechanical traps in which no sticky substance is involved; these are the non-constricting ring and the constricting ring, both of which operate on the principle of a rabbit snare. The non-constricting type of ring is found in *Dactylaria candida* (Nees) Sacc. (16,) a Hyphomycete, recorded from soils. Each ring trap is composed of 3 curved cells and is attached to the mycelium by a stalk; the diameter of the ring is such that if a nematode attempts to pass through the opening, it becomes wedged and cannot withdraw and as the rings are very numerous, nematodes may be captured in large numbers. The action of the ring is passive, the prey being held purely by its having forced itself into the ring in attempting to pass through. Drechsler (11) records that in cultures, nematodes circled by as many as half a dozen rings may be seen indicating a like number of escapes. Nematodes that free themselves in this way do not live long, however, for their bodies are invaded by trophic hyphas from the ring, so that they eventually suffer the same fate as those which have been held by the fungus. When this happens, a new mycelium grows out from the carcass of the dead nematode, so that rings that have been torn away can serve

as a means of vegetative propagation—a fact that led Sherbakoff (32) to mistake non-constricting rings for conidia.

Hyphomycetes with non-constricting rings, including *Dactylaria candida*, are often provided with stalked adhesive knobs, the stalks usually being distinctly longer than in those species in which the knob is the only form of trap. Where these two traps occur together in the same fungus, the knobs may be partly or completely functionless.

The non-constricting ring acts passively. In the constricting ring, the most remarkable of all the nematode traps, the prey is caught by positive action of the ring itself. Morphologically, the constricting ring is not unlike the simpler non-constricting form, but it is more robust, and the two-celled stalk is shorter and stouter. Each ring is formed from 3 cells, each cell being curved to form an arc, the 3 cells joining up to form the ring, with a stalk attached between 2 of the cells. If a nematode passes its head into the opening of a ring, the friction of its body stimulates the ring cells to swell rapidly to about 3 times their former volume, the opening in the ring being virtually obliterated with the result that the nematode is tightly gripped. The swelling of the ring cells is very rapid, complete distension being reached in about 1/10 of a second after the onset of the reaction. The nematode is deeply constricted by the pressure of the swollen ring cell so that escape is impossible. The death of the nematode is followed by the growth of trophic hyphae into its body to absorb its contents.

The nematode-trapping Hyphomycetes reproduce asexually by means of conidia formed at the apices of erect fertile hyphae, and distinctions between the genera depend on the structure of the spores and the number of spores per conidiophore. It has only recently been recognized (21) that the ability of a particular spore to form a hypha which may or may not form constricting rings depends upon the nuclear arrangement within the particular conidia, this being a heterocaryotic condition in certain of these fungi.

The endozoic Hyphomycetes develop their mycelia within the bodies of nematodes, only the fertile hyphae bearing the conidia appearing outside the body of the host. The animals are usually infected by means of spores that stick to their integuments, the germ tubes from the spores penetrating through the skin of the animals and giving rise to an internal mycelium. The spores of these fungi are usually very small and are formed in very large numbers, as might be expected since the wastage must be great. Some of the commonest of the predaceous fungi are found in this group.

The various species of *Harposporium* are characterized by spores that are elongated and curved, bent, or twisted. *H. anguillulae* is extremely widespread in a variety of different habitats. This fungus is commonly found in citrus groves in Florida. It has also been found all over the world in different types of cultivated and non-cultivated soils. There is some controversy concerning the method by which this fungus infects nematodes. It was originally thought that the nematodes were infected by the sickle-shaped conidia which become attached to their integuments, the germ tubes penetrating into the host and forming within it a branched mycelium of septate hyphae. The recent work of Aschner and Kohn (1), however, has cast some doubt upon this theory. They were apparently able to grow *Harposporium anguillulae* in pure culture, this being the first report of one of these obligate parasites being grown in pure culture. They found that under pure-culture conditions the nematodes became in-

fected by ingesting the small conidia, the infection process then taking place as usually described once the spores had been ingested. This author has thus far been unable to confirm the work of Aschner and Kohn. It will be important to learn whether their results are correct as to the infection through the ingestion of spores, since if this is the case these organisms which seem to hold great promise for biological control would be of little value in controlling the plant-parasitic nematodes since they would be unable to ingest spores of this size. Another endozoic species that is widespread in British and American soils is *Acrostalagmus obovatus* (13).

The genus *Nematoctonus* (13) differs in a number of respects from the other endozoic predaceous fungi. The spores are relatively large and are formed on lateral sterigmata; both the fertile hyphae and the vegetative mycelium within the host are coarser and an interesting feature is the presence of well-developed clamp connections. Clearly, *Nematoctonus* is far removed taxonomically from the others, and the clamp connections suggest that it is an imperfect member of the Basidiomycetes. The large spore size strongly suggests that this fungus attacks by means of cuticular attachment rather than by the spores being ingested by many of the small nematodes found attacked by it.

The various studies on the inducing of constricting rings and on the various stimuli which cause the closure of these rings, have been thoroughly reviewed by Duddington (17, 18). Suffice it to say here that the constricting rings are apparently formed in the presence of certain stimulatory materials and that the closure of the rings is a tactile response whose mechanism is poorly understood. In addition, the ability of a particular fungus to form rings is now known not to be homogeneous from spore to spore but tremendous variations take place in some of these fungi because of the heterocaryotic nature of their mycelium and conidia. In addition, since Duddington's reviews were written, further work on the isolation of the ring-forming stimulus has been carried out by Pramer and Glaser (31). They have characterized the ring-stimulating material as a complex chemical probably not related to the antigenic materials secreted by some nematodes. They have obtained this chemical in a fairly purified state and are, therefore, able to make quantitative studies of it at various dilutions.

Before experimental attempts to control plant-parasitic nematodes by using the predaceous fungi are discussed, a number of other microbial pathogens of nematodes should be mentioned briefly. There have been numerous observations of bacteria occupying the gut and the body cavity of various nematodes. Pages of Dollfus (15) are filled with drawings showing various shadowy or granular areas in nematodes which are described by their authors as being bacterial in origin. In addition, there have been some observations upon sporozoan infections in the guts and body cavities of nematodes. Some of the illustrations of sporozoan infections are obviously just that. However, there are other such infections recorded which might well be examples of polyhedral viruses or other similar entities. None of these studies have been carried out in recent times and none are well documented. Here lies a new field of investigation open to anyone who can develop the necessary techniques. The successes realized by entomologists using bacterial and viral agents as biological control organisms should spur on this type of investigation. In addition, there have been numerous observations on the destruction of live nematodes by other nematodes and various mites. The mite literature is rather scanty; however, there is a rather voluminous record of predaceous nema-

todes feeding on various saprophytic and plant-parasitic nematodes.

However, the bulk of experimental work, both control and taxonomic, has been done on various predadeous fungi. Those most often studied have been the predaceous Hyphomycetes, since these are easily cultured on ordinary culture media and are readily recognizable in culture and in nature. Little work has been done with the Zoopagales and a minimal amount of work has been done with the endozoic Hyphomycetes. Until recently (1), the latter appeared to be obligate parasites and were therefore, considered too difficult to manipulate successfully under laboratory conditions.

During the past 20 years various workers have turned their attention to the use of predaceous fungi for the biological control of plant-parasitic nematodes. The earliest experiments were carried out in Hawaii by Linford and his colleagues, working on pineapple root-knot nematode. In one series of tests, attempts were made to stimulate the activity of the predaceous fungi already present in the soil by adding chopped pineapple tops. This was found to lead to a great increase in the numbers of free-living nematodes, followed in turn by the increase in activity of the predaceous fungi, so that the final result was a reduction in the nematode fauna, which included infective larvae of the root-knot nematode. Linford claimed to have produced in this way striking reductions in the number of larvae of the root-knot nematode, which effects he maintained were statistically significant (26, 28, 29).

This work received support from an experiment on the control of the cereal root nematode *Heterodera major* Schm. in oats. (Duddington and Duthoit, unpublished.) Here the addition of chopped cabbage leaves to soil artificially infested with cysts of *H. major* protected the oats from attack by the nematode, untreated control plants being badly damaged. Soil samples showed that in the treated plots predaceous Hyphomycetes, especially *Arthrobotrys oligospora* and a variety of *Dactylaria thaumasia* Drechsler, were more active than in the control.

In a further experiment, Linford and Yap (27, 29) attempted to control pineapple root-knot nematode by the addition to the soil of cultures of the predaceous Hyphomycetes *Arthrobotrys oligospora*, *A. musiformis* Drechsler, *Dactylaria thaumasia*, *Dactylella ellipsospora*, and an unidentified species of *Dactyella*. After 15 months, comparisons of plant growth obtained with the various treatments indicated a slight measure of control over the nematode with *D. ellipsospora*, the other fungi being apparently without effect.

About two decades ago, some interesting work on nematode control was carried out by a group of workers in France. Much of this was concerned with demonstrating that, under laboratory conditions, predaceous Hyphomycetes are capable of attacking nematodes parasitic in plants and domestic animals, the fungi used being *Arthrobotrys oligospora*, *Dactylella bembicodes*, and others. Descazeux (3) showed that the fungi were able to destroy large numbers of pathogenic nematodes in dung cultures. He also showed that these fungi could be used effectively in liquid culture, using dung infusion, and the use of predaceous fungi for the decontamination of water containing nematodes parasitic in animals was suggested but never followed up (4).

Deschiens (5) described a method of extracting nematode larvae from dung cultures and also demonstrated the susceptibility of various nematodes from monkeys, sheep, and cattle to attack by *Arthrobotrys oligospora*

and *Dactylella bembicodes*. This same author also demonstrated that the root-knot nematode in begonia could be captured; this was one of the few occasions when a plant pathogen was used as test organism by the French workers, most of their experiments having been concentrated on the veterinary problem. In 1943 Deschiens, Lamy, and Vautrin (6) attempted to protect begonia plants from attack by root-knot nematode by using *Arthrobotrys oligospora* and *Dactylella bembiocodes*. It was found that both the percentage of plants showing infection and the mean number of galls per infected root were greatly reduced by the fungus treatment. This experiment was carried out on a small scale and was never repeated.

The work of Linford in Hawaii, supplemented by more recent work of Duddington in England, seems to indicate that the activity of predaceous fungi in the soil is markedly stimulated by the addition of organic matter to the soil. The results of numerous experiments carried out in Hawaii and in England indicate that the increased predaceous fungus activity seems to confer some measure of protection on the plants growing in nematode-infested soil. Further, the plant response seems not to be due to the quantitative addition of organic matter, since in some of Duddington's experiments, the amount of organic matter added to the soil in micro plots in the field was infinitesimally small. However, Linford's view may be correct in this instance: namely, that the addition of organic matter stimulates the rapid reproduction of saprophytic soil nematodes. These stimulate the development of the predaceous fungi which in turn are then capable of capturing the larvae of various plant-parasitic nematodes present in the soil at that time. Interesting work at the University of Birmingham in England also indicates that on a laboratory scale at least, the predaceous fungus activity in soils can be readily stimulated by very small additions of organic matter and that these increases in predaceous fungus activity are always correlated with a great increase in the numbers of free-living saprophytic nematodes. Other work by Duddington (18) indicates that the effect of organic matter in conjunction with addition with a particular predaceous fungus was greater than where either one was used alone. In one experiment in a field infested with the golden nematode *Heterodora rostochiensis* the following 4 treatments were used: (1) Dung, with the addition of *Dactylaria thaumasia*, a fungus capturing eelworms by adhesive networks. (2) Dung only. (3) Cultures of *D. thaumasia* in a sand and corn meal mixture. (4) No treatment. The plots were sown with potatoes, variety 'Record,' and given normal cultivation. The rows that had received fungus and dung produced a healthy crop at the rate of about 10 tons of potatoes per acre. The tops showed no sign of nematode damage and there were no gaps in the rows, though the roots bore numerous nematode cysts. Where dung was given without the fungus the crop was badly damaged by nematode, about two-thirds of the plants being stunted or killed. The crop amounted to less than 5 tons per acre, and the proportion of good potatoes was low. The rows that had received fungus without dung could not be distinguished from the untreated controls; at the end of the summer these rows were a mass of chickweed with a few badly stunted potato plants showing here and there, and the crop, such as it was, produced a hundred weight or two of 'pig potatoes' per acre, with a few good tubers (18). Here, where the fungus had been used in combination with dung, the nematode had been controlled sufficiently to allow a good crop to be taken; dung alone failed to do this, and where no dung was used, the fungus was not successful in protecting the crop.

Recent work in the United States by Lear (25) and Johnson (23) also suggested that organic-matter additives in some way influenced the activity of predaceous nematode-attacking fungi, but again no real clues as to the mechanism by which the organic matter acted is given. Mankau and Clark (30) found a number of nematode-trapping fungi in California citrus soils but the work of De Wolfe et al. (7) using mulches in citrus groves showed a stimulation of predaceous fungus activity but no concomitant decrease in citrus nematode populations.

What needs to be done:

We have before us now much information on the genera and species of predaceous fungi which destroy nematodes in some fashion. We have some indication that the organic-matter content of soils has some influence, direct or indirect, on activity of predaceous fungi. We have some indication that under certain conditions the predaceous fungus population can be stimulated enough to reduce damage to plants by plant-parasitic nematodes. Attempts to control the attacks of plant-parasitic nematodes by the use of predaceous fungi have been disappointing and will continue to be so until we have a great deal more basic information.

If we are to use fungi and other microorganisms to control plant-parasitic nematodes we must first begin thinking about them in their natural associations with the rhizosphere microflora and fauna rather than as isolated organisms living an independent existence in the soil. We must work with soil microbiologists and plant physiologists to discover how microorganisms are affected by the plant roots which they live on and near. We must learn more about what actually happens to the equilibria of soil populations after the addition of various outside sources of organic matter. Studies must be made of the nutritional requirements of some of the predaceous fungi so that we can most effectively stimulate their growth, reproductivity, and predaceous habit. Methods of collecting and storing large numbers of spores and other infective material must be explored. Nematodes infected with one of the endozoic predaceous fungi have been successfully freeze dried (20). This material kept its infectivity for 6 months. No doubt, pure spore material could be held even longer. To date, no method of assaying for the activity of predaceous nematode-attacking fungi in soils has given information which would be useful in comparing soils for this type of activity. This information is a "must" if we are to proceed in an orderly fashion. We must learn more about the genetic mechanisms which control sporulation and the production of nematode-trapping devices in the predaceous fungi. There are now indications that tremendous variations in the ability to form trapping devices exists in some of these organisms (21). Further, an understanding of the forces controlling these variations will enable us to produce organisms which are far more efficient nematode trappers. The heterocaryotic nature of the mycelia of some of these fungi gives us a rich source of understandable variability which we should be able to turn to our own ends. The descriptive phase of our studies on the predaceous nematode-attacking fungi is not over, but if we are to make progress, emphasis must be shifted to studies which will help us understand more about how these organisms grow and reproduce and where they fit into the total scheme of a living soil.

In addition, more attention must be paid to discovering whether bacteria and viruses can actually act as nematode pathogens. The techniques

and methods may be difficult to evolve but the results, if positive should prove of perhaps even greater utility to us in our attempts to control nematodes with other living organisms or their by-products.

I have purposely avoided coming to grips with the problem as it relates to tropical or subtropical or any specific geographical area. Suffice it to say, members of the predaceous fungi have turned up everywhere. In addition, it should be clear that the results of basic studies such as outlined are applicable to agricultural problems involving nematodes wherever they may occur, regardless of where the original research is done.

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BANQUET AND BUSINESS MEETING

The Annual Business Meeting of the Society followed the Monday evening (Nov. 30) meeting of the first day of the sessions in the auditorium of Dan McCarty Hall, College of Agriculture, University of Florida, Gainesville. It was called to order by President P. H. Senn and the usual routine of business taken up including committee reports and that of the Secretary on membership and publication and the presentation of the Treasurer's interim report, the final report as usual to be prepared at the close of the calendar year for auditing and publication in the Proceedings (Vol. 19, 1959). The reading of the minutes of the previous meeting was dispensed with in view of the completeness of the published record in Proceedings Volume 18, 1958.

MEMBERSHIP

Insofar as response to the increase in dues has been had up to the close of the year it has been excellent. Not the first remonstrance has been raised. I am pleased indeed to read a particularly interesting letter that touches somewhat more than slightly on this subject, from one of our most illustrious members residing in Latin America. Reference is to a letter dated November 20, 1959 from Dr. Ralph H. Allee, Director of Instituto Inter-Americano de Ciencias Agricolos, Turrialba, Costa Rica, as follows:

Dear Allison:

> Due to the pressure of less important things I will not be able to attend the Nineteenth Meeting. I regret that you have organized such a good one when I have to be elsewhere. Will look forward to the proceedings.
>
> Attached my check for $3.00. It is still the best buy on the market.
>
> Sincerely,
> (Signed) Ralph H. Allee
> Director

Many, many others have been similarly friendly and altogether favorable.

Particular note also should be taken of the reaction of those companies carrying a considerable number of their staff as annual members, supplemental to their Sustaining Membership. To date the reaction in this instance also has been wholly favorable even in the instance of one which has been carrying 32 such members in addition to a Sustaining Membership. We can only say that such interest in and support of the work of the Society is deeply appreciated.

Something of a new touch was added to the Sustaining membership approach when the Fertilizer Division of Wedgworth's, Inc., of Belle Glade, gave us such a membership and asked that, under it, a copy of the Proceedings be sent to the library of each High School in the city. This, it would seem, is an idea well worth developing. Later, Hamilton Growers, Inc., Lake Hamilton, also asked that a copy of Proceedings Volume 18 be

sent to the Winter Haven High School under the Sustaining Membership of this company with their compliments.

In general it can be said that there has been a very satisfactory consolidation and advancement in the membership of the Society at both levels, regular and sustaining, during the year. This is reported in detail in the following table showing the geographical distribution of membership as of the close of the year.

GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIP

	Annual		Sustaining		Honorary Life		Total	
	1/15/59	1/15/60	1/15/59	1/15/60	1/15/59	1/15/60	1/15/59	1/15/60
Florida	546	545	94	85	1	1	641	631
U.S. (other than Fla.)	178	175	35	35	7	7	220	217
Caribbean	77	81	6	6	_	1	82	88
Foreign	31	42	8	6	1	1	41	49
Total	832	843	143	132	9	10	984	985

REPORT OF TREASURER

As has been practiced in the past, with the approval of the Executive Committee, the financial report of the Society, as published herewith is made to cover the calendar year rather than close at the time of any particular annual meeting. This is for the obvious advantages that already have been quite fully discussed. The report of the Treasurer follows:

Statement of Receipts and Disbursements
January 1, 1959 thru Dec. 31, 1959

Cash in bank Jan. 1, 1959—Florida National Bank		$3,803.48
RECEIPTS:		
Regular dues	1,654.00	
Sustaining dues	1,900.00	
Proceedings sold	153.00	
Donations	2.50	
Postage refund	.15	
Registration at annual meeting	294.00	
		4,003.65
Monies to be accounted for		$7,807.13
DISBURSEMENTS:		
Office supplies	23.59	
Postage	352.81	
Printing—Volume 18	3,687.46	
Bank charges	2.60	
Expenses of annual meeting—1959	173.59	
		4,240.05

Cash in bank Dec. 31, 1959		
Florida National Bank	440.08	
Everglades Federal Savings and Loan Co.	3,127.00	
		3,567.08
Monies accounted for		$7,807.13

PUBLICATION

Again the Proceedings, Volume 18 for 1958, has exceeded all earlier volumes in size and, of course, also in cost of publication. However, it is felt the quality of the paper used as well as the stitching of the volume which allows it to open out flat and provides no metal staples to immediately start rusting makes the rather high cost of publication worth while after all. Perhaps this will add to the greater care and more intimate use the volume will receive during the year.

Our geographic distribution as to membership and mailing of the Proceedings continues to grow. Thus we have penetrated both curtains—Iron and Bamboo, with two mailings in the former instance and one in the latter. The Proceedings of the Society is now being mailed to individuals, companies and public libraries in 47 different countries.

TWO DECADES OF MEETINGS IN REVIEW

If your secretary may do so briefly, he would like, in the review spirit of the present meetings, to point out at least a few of the highlights in the programs of the Society that have been developed thru these twenty years, the body total of which, including the current volume (19) consists of 524 papers, about two thirds having appeared in the form of 51 carefully prepared symposia.

In this it is a pleasure to call particular attention to a few sections of this record that continue to appear outstanding. Thus special mention might be made of:

1. The first symposium on soil and plant relationships to animal and human nutrition, Proc. Vol. II, 1940. This is just about the first of this type of orderly discussion on this general subject to be found anywhere in the literature and well represents the continuing interest of the Society in this field of human and animal welfare as it so importantly relates back to the soil and the plants growing in it. This was followed in 1950 (Proc. Vol. X) by what amounted to a worldwide review in this field but which could cover only plant and animal relationships, this important field of research and study having grown to such proportions in the meantime.

2. Statewide soil survey law, 1941, was written and fully sponsored by the Soil Survey Committee of the Society under the leadership of Senator Ernest Graham as chairman of that committee with the very capable assistance of the late Dewey Hooten who at that time was Executive Secretary of the Florida State Planning Board. The reaction of both Houses of the Legislature to the Bill under this sponsorship was very outstanding and almost unique in that it passed both unanimously with the exception of less than a half dozen votes in the House of Representatives.

3. The first interim meeting of the Society for the discussion of the

physical and economic problems of the Florida Everglades was held in the spring of 1942 in West Palm Beach (Proc. Vol. IV-A) and the second interim meeting on the same subject was held in Belle Glade in the spring of 1943 (Proc. Vol. V-A). Both of these meetings were carefully planned and the papers and discussions published. Without doubt it was the accomplishments of these two meetings and the fine part taken in them by Commissioner of Agriculture, Honorable Nathan Mayo and many others, including Mr. Wallis himself, which served as background for a statement by W. Turner Wallis when he said "if it had not been for the Soil Science Society of Florida there would be no Central and Southern Florida Flood Control District." This was in the course of the 1956 meeting of the Society in Clearwater in which water conservation as a Statewide problem was given an important part in the program.

4. Meeting devoted entirely to control of water weeds. Proc. Vol. IX, 1949. The significance of this effort with the use of such chemicals as 2-4-D which was initiated at the Everglades Experiment Station in 1945 is clearly indicated by the comparative freedom from hyacinths of the arterial canal system at the present time as well as such lakes as Monroe, near Sanford, which but a few years ago was observed to be a third to a half covered with this widespread pest.

5. Symposium (1959) on nematology as a pressing field of study hemispherically (Proc. Vol. 19) when considered along with one of the first symposiums on this subject (Proc. Vol. IV-B, 1942) shows in quite a definite way the long time interest of the Society in the control of one of the most insidious pests with which agriculture is confronted just about everywhere on the globe.

REPORT OF COMMITTEES

Nominating Committee: This committee consisting of Drs. F. B. Smith, George D. Thornton and Fred H. Hull, which had been appointed by President Senn well in advance of the meeting, presented as its candidate for the only elective office, the vice presidency, Mr. Willis H. Chapman, Agronomist in Charge, North Florida Experiment Station, Quincy. There being no nominations from the floor upon call from the Chairman of the meeting Dr. Hull, spokesman for the nominating committee, moved that the nominations be closed and the Secretary instructed to cast a unanimous vote for Mr. Chapman. With several prompt seconds and no questions Mr. Chapman became the new Vice President of the Society and by force of precedent, the Chairman of the Program Committee for the coming year.

Resolutions Committee: The Resolution of Sympathy read by the Secretary told of the loss by death of three valued members of the Society during the year. The reading was followed by a brief period of silence at the request of the President. This resolution will be found published in full on page 471 of this volume.

INTRODUCTION OF A NEW LIFE MEMBER

An item of outstanding interest was the announcement by the President of the nomination to Honorary Lifetime Membership in the Society of

Dr. Wilson Popenoe of Guatemala by the Executive Committee to take the place left vacant by the passing of our great and good friend, Charles F. Kettering. This is a recognition not only for the tremendous contribution Popenoe has made to agriculture in the Tropics of the world in general and to that of our own Latin American countries in particular, but also for the constructive and helpful interest he has always shown in the development of the work of the Society from its very inception. Although Dr. Popenoe had definitely planned to attend the meeting, unfortunately he found almost at the last moment that he could not. In his absence his son, Hugh, accepted the honor for him and fortunately was able to tell him about it in the next few days in the course of a visit home which had been planned at that time.

PASSING OF THE GAVEL

The actual "passing of the gavel," our very first real one, the thoughtful gift of our long time friend and charter member, Mr. R. L. Bryan of Bartow, did not occur, however, until after the banquet on Tuesday evening, December 1. This ceremony followed the exceedingly timely and inspirational address of our own Dr. Marshall O. Watkins, Director of the Agricultural Extension Service in Florida, under the title "Development and Present Status of Extension Programs in Soils and Field Crops in Florida" and the very interesting greetings from the Cornbelt as conveyed by Dr. George D. Scarseth, Director of Research, American Farm Research Association of LaFayette, Indiana. This officially placed the Vice President of the past year, Mr. J. R. Henderson, in the chair with only sufficient time to express his heartfelt thanks for the honor bestowed upon him and give assurance of his very best efforts towards the advancement of the work of the Society during the year before he brought the meeting to a close. Provost for Agriculture, Dr. Willard M. Fifield, acted as Master of Ceremonies at the banquet.

MEETINGS OF THE EXECUTIVE COMMITTEE

A—Interim Meeting, April 19, 1959, Dan McCarty Hall, College of Agriculture Gainesville, Dr. P. H. Senn, President, presiding.

The meeting was called to order at 1:30 P.M. by Chairman Senn. The principal purpose of the meeting, which included the entire committee, was to finalize the dates of the Nineteenth Annual Meeting in December and to discuss details of the program. November 30 and December 1 and 2 were decided on as best fitting in with the Annual Caribbean Conference that is to be held on the campus at the University of Florida later in the same week.

The Chairman of the Program Committee, J. R. Henderson, reported on a quite completely outlined program plan centering around twenty years of progress in soils and crops research and extension in Florida. This was accepted for development and made to include a symposium on nematology with a hemispheric viewpoint of this ever-expanding problem.

It was decided to continue the distribution of any available volumes of the Proceedings, up to and including Volume 19 (1959) at $1.00 per copy as in the past but to charge $3.00 per copy for Volume 20 (1960) and those that follow, in line with the increase of the annual dues to that amount beginning at that time.

It was decided to dedicate Proceedings Volume 19 to the Extension Personnel and their accomplishments. With this thought in mind the Secretary was instructed to write each worker in the Service regarding these plans and invite all to membership in the Society who have not already joined.

Decision also was taken to delay any letter to the membership advising of change of dues, program plans, etc, until about mid-November when it could also serve as the regular annual announcement.

Contact of the program chairman with what has been recognized as a standing committee for several years, namely, heads of interested departments in the College of Agriculture and those in charge of Branch Stations and Field Stations over the State, was discussed at length and left in his hands both as to panel presentations and contributed papers.

The Secretary was requested to make further contact with Dr. A. C. Tarjan, Nematologist, Citrus Experiment Station, by way of confirming the invitation of the committee to assume the responsibility for developing a symposium on nematology with particular emphasis on the hemispheric viewpoint on the one hand and biological control on the other. This, it was learned later in the same afternoon as the meeting, he would be willing and pleased to do.

The Committee nominated Dr. Wilson Popenoe of Guatemala to Honorary Lifetime Membership in the Society in the place made vacant by the death of Mr. Charles F. Kettering during the past year. Dr. Popenoe is famous throughout the tropical world for his work with soils and crops of all sorts both agronomic and horticultural. His very great interest in the development of the Society from its humble beginning has been a continuing inspiration to those who have been most active in the work.

There being no further business to come before the Committee the Chairman declared the meeting adjourned at 3:15 P.M.

B—A brief meeting of the Executive Committee, immediately following the banquet (December 1) was called to order by President Henderson with all members present.

The first item of business was the reappointment of R. V. Allison, Belle Glade, as Secretary.

The place and time of the next meeting was discussed tentatively as somewhere in Central Florida and later settled by correspondence among the committee members as Clearwater on November 28, 29 and 30 with Hotel Fort Harrison as headquarters. The dates were selected as synchronizing in the same way as in the past few years with the meetings of the Caribbean Conference on the campus of the University of Florida on December 1, 2 and 3.

In discussing prospective subject matter for the program of the 20th annual meeting it was decided to continue in an emphasis on contributed papers with some consideration being given to another (10 year) review of soil and plant relationships and their particular importance to both human and animal nutrition and welfare, the first symposium on this general subject having appeared in Proc. Vol. II, 1940 and the second in Proc. Vol. X, 1950.

The need for a reprinting of membership forms was discussed and the Secretary authorized to order same. A rather extensively developed membership committee (permanent) to be nominally chairmanized by the President, was discussed briefly and remanded to correspondence and personal contacts during the year for further consideration as was also the

idea of again organizing a number of standing committees to cover each of the more important subject matter fields of the Society. It was agreed that carefully organized and properly administered this could form a very strong background for the future work of the organization.

Following trials with makeshift forms for use at the time of the annual meetings it was agreed as desirable that further efforts be made at providing those whose membership falls under the Sustaining Membership of a company or association with some form of identification card to present at the desk upon registration so that attendance upon meetings for such individuals can be facilitated without embarassing questions being raised regarding dues and, at times, the collection of annual dues from "undue" sources.

It was agreed that the idea of Sustaining Members, such as well known companies, sponsoring the gift of the Proceedings to the library of their local high school is in good order and should be encouraged.

There being no other business to come before the committee the chairman declared the meeting adjourned at 10:45 P.M.

RESOLUTION OF SYMPATHY

WHEREAS, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come,

NOW, THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

Felix Brecher
Fallbrook, California

John T. Pickett
Pahokee, Florida

Norman C. Storey
Youngtown, Ariz.

P. H. SENN

OFFICERS OF THE SOCIETY
1959 Retired

P. H. SENN	President
J. R. HENDERSON	Vice-President
G. D. THORNTON	Past President
R. V. ALLISON	Secretary-Treasurer

Constitution and By-Laws of The Soil and Crop Science Society of Florida (Revised)

NAME

Article I.
The name of this organization shall be The Soil and Crop Science Society of Florida.[1]

OBJECTIVES

Article II.
The objectives of this Society shall be to foster all phases of Soil and Crop Science, both as to its development and application, namely, in the fields of research, teaching and extension.

MEMBERSHIP

Article III.
Any person or organization interested in the objectives of the Society shall be eligible to membership in the Society.

SECTIONS

Article IV.
The integration of the activity of the Society shall be limited to certain functional committees until it becomes evident that sectionalization on the basis of subject matter will serve a definite purpose in advancing the work. Such committees will be appointed each year.

AFFILIATION

Article V.
This Society may become affiliated, as a State unit, with such National Societies as the Soil Science Society of America provided the requirements of such affiliation are not such as to be at variance with the provisions of the Constitution of the Florida Society.

OFFICERS OF THE SOCIETY

Article VI.
The officers of the Society shall be a President, a Vice-President, a Secretary-Treasurer, and an Executive Committee. The Executive Committee shall consist of the President of the Society (Chairman), the Vice-President, the Secretary-Treasurer, and the most recent past president.

ELECTION OF OFFICERS

Article VII.
The President shall appoint a nominating committee of three members in advance of the annual meeting. This committee shall nominate a candidate for Vice-President, the Vice-President for the year automatically succeeding to the presidency. Other nominations may be made from the floor. Election of the Vice-President shall be by ballot. The term of office shall be for one year. The Secretary-Treasurer shall be appointed by the Executive Committee.

DUTIES OF OFFICERS

Article VIII.
Section 1. The President shall be the Executive Officer of the Society. He shall preside over the meetings of the Society and its Executive Committee. He shall be responsible for the arrangement of the programs of the Society with the help of the Executive Committee and such other assistance as he may appoint or request.
He shall appoint such committees as may be deemed advisable by the Executive Committee under Article IV of the Constitution or as may be requested or directed from the floor by majority vote.
He shall continue to serve on the Executive Committee of the Society for one year following his retirement from the presidency.

Section 2. The Vice-President shall be elected annually by ballot from the slate prepared by the nominating Committee supplemented by any nominations from the floor. He shall act for the President in his absence and otherwise assist him with the duties of that office.
He shall automatically succeed to the presidency of the Society at the expiration of his annual term.

Section 3. The Secretary-Treasurer shall be appointed by the Executive Committee.
He shall keep the minutes of all regular meetings and the financial records of the Society.
He shall pay the bills of the Society, following the approval of the President.
He shall act as Secretary and as Editor of the Executive Committee in its function as an Editorial Board.

Section 4. The Executive Committee shall outline the program of activities and formulate the policies of the Society.
It shall recommend functional committees for appointment under Article IV of the Constitution.
It shall act on all matters arising between the regular meetings of the Society.
It shall act as the Editorial Board of the Society of which the Secretary-Treasurer shall be the Editor.

TIME AND PLACE OF MEETING

Article IX.
The annual meeting of the Society or any joint meeting of the Society with other societies shall be at a time and place determined or agreed upon by the Executive Committee of the Society.

AMENDMENTS

Article X.
Amendments may be proposed (1) by the Executive Committee directly or (2) by petition of any ten (10) members of the Society. The amendment may be adopted by a two-thirds vote of the members present at any annual meeting, provided notice of same has been distributed to the membership of the Society at least fifteen (15) days previous to the meeting at which it is to be acted upon.

BY-LAWS

1. *Dues.* The annual dues for membership in the Society shall be three dollars ($3.00).[2]

2. *Expenditures.* Bills for any expenditures made by the officers of the Society in transaction of official business, after approval by the President of the Society, shall be submitted to the Treasurer for payment.

3. *Committees.* Such standing and special committees may be appointed by the President as seems desirable to carry on the work of the Society, as provided by Article VIII, Section 1, of the Constitution.

4. *Quorum.* A quorum at the annual meeting or any other business meeting which may be called shall consist of at least 20 per cent of the members.

5. *Amendments.* The by-laws may be amended at any regular meeting of the Society by a two-thirds vote of the members present.

Adopted in Organization Session
Hollywood, Florida
April 18, 1939.

[1]Revised, Nov. 30, 1955. Recorded in Proceedings XV 1955 p. 251.
[2]Revised, Dec. 1, 1958. Recorded in Proceedings 18 1958 p. 368.

Author's Guide for Preparing Papers for the Soil and Crop Science Society of Florida Proceedings

The following suggestions for preparing papers to be published in the Proceedings of the Soil and Crop Science Society of Florida are taken primarily from the "Author's Guide and Style Manual" prepared and published by the American Society of Agronomy.

FORMAT

The following general outline is well suited for the majority of Soils and Crops research reports:

Introduction
Literature Review
Materials and Methods
(or Experimental Procedure)
Results
Discussion
Conclusions
Summary
Literature Cited

FOOTNOTES

1. Footnotes should be typed, double spaced, in numerical order, at the bottom of the first page and succeeding pages where appropriate.

2. Number them consecutively from 1. Do not use any other symbols for footnotes to the *text*.

3. Use number 1 for documenting the paper. That is, refer to Jour. Series Number, Agricultural Experiment Station, or, denote joint contribution between two agencies as State Experiment Station and U.S.D.A. workers.

4. Use number 2 to identify authors.

5. Include as footnotes all unpublished M.S. and PhD. theses, personal communications, unpublished departmental or station records, and other unpublished material not generally available in libraries when reference to these is made in text.

LITERATURE CITATIONS
(Examples)

Periodical

Carver, H. L. and W. K. Robertson. A study of some laboratory methods for determining calcium and magnesium. Soil and Crop Sci. Soc. Fla. Proc. 16: 258-271. 1956.

Bulletin

Thompson, L. G. and W. K. Robertson. Effect of rotations, fertilizers, lime and green manure crops on yields and soil fertility. Florida Agr. Exp. Sta. Bul. 522. 1953.

Book

Jones, A. B. Corn Breeding. Smith and Smith. New York. p. 100. 1940.

Book, Part of

Overstreet, H. A. The psychology of effective writing. *In his* Influencing Human Behavior. Norton, New York. pp. 87-109. 1925.

(General rules)

Use footnotes for three or less citations. The use of the number reference—Adams (1)—is preferable. In references to titles by three or more authors use "Jones *et al.* (1)" in text but use all author's names in the citation, e.g. I. Jones, R. G., A. B. Smith and S. D. Brown.

USE OF ABBREVIATIONS

1. Do abbreviate state names, except Idaho, Iowa, Maine, Ohio and Utah, when immediately following geographic place: Gainesville, Fla.

2. Do not abbreviate state names when used other than above in text or footnotes: Soils of northern Florida; Contribution from the Florida Agr. Exp. Sta.; Florida Agr. Exp. Sta. Bul. 392.

3. Spell out all English weights and measures, except cwt. in text: pounds, inches, foot, feet, ton, acre, etc. These may be abbreviated in tables to conserve space.

4. Abbreviate all metric units: M., Cm., mm., cc., g., mg., l., ml., etc. except at the beginning of a sentence and when used without a number: Twenty grams, The gram weight—etc. Close all metric abbreviations with period.

5. Avoid using expression as "100 lbs A" in text.

6. Other accepted abbreviations: ppm (parts per million); me (milliequivalent); psi (pounds per square inch); C (Centigrade); F (Fahrenheit); spp. (species); ave. (average) in tables *only*.

7. Use % sign in all cases with numerals; spell as one word—percent—when used without numerals.

8. Use the unit only at the end of a series or range; e.g.: 7, 10, 13, and 20° C.; 3 to 7 feet.

9. Spell out "Figure 2" in text but abbreviate in legends, "Fig. 2."

CAPITALIZATION

1. Capitalize "state" and "county" only when used before or after a state or county name: Alachua County, State of Florida.

2. Capitalize: North Atlantic states, the South, southern Gulf states, northern Florida, Citrus Belt or Cotton Belt; genera, families, orders, but, *not* specific names of plants.

3. Do not capitalize a.m. and p.m.

TABLE STYLE

TABLE 1.—INFLUENCE OF LIME ON YIELD AND INCIDENCE OF WILT AND ROOT ROT OF ALFALFA, 1958.

Treatment	Yield[1]	Plants with:	
		wilt	root rot
Tons/A	Lbs/A	%	%
0	1000	23.0	20.0
2	3000	25.0	15.6*
4	4500	24.0	12.1**

[1]Based on air dry weights.
* Significant at the 5 percent level.
**Significant at the 1 percent level.

In general, the title of a table should be so stated and its contents so arranged as to be readable and understandable without reference to the text. The same also could well be expected of the legends for figures or plates and their drafting or arrangement.

THE GALLEY AND PAGE PROOFS

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Note: The Executive Committee will always regard it a real favor if any member will report needed corrections in his own listing or that of other members whether as to title, address or spelling. Ed.